LABORATORY DIRECTIONS IN COLLEGE ZOOLOGY

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LABORATORY DIRECTIONS
IN
COLLEGE ZOOLOGY

BY
HENRY LANE BRUNER
PROFESSOR OF ZOOLOGY IN BUTLER UNIVERSITY

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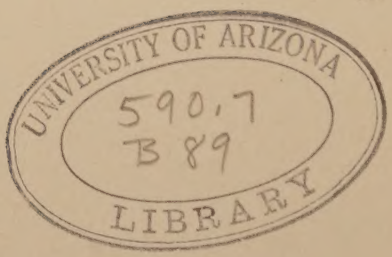

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PREFACE

The instructor who attempts to organize a course in general zoology faces the difficult task of selecting material from various departments of zoological knowledge and adapting it to students who have entirely different interests. Wide differences of opinion in regard to the content of such a course and the order of treatment are indicated by the variety of courses offered. The experience of the writer has led him to adopt a course which proceeds from simple to complex forms and emphasizes morphology, while at the same time it gives due consideration to other aspects of zoology.

The introductory course in zoology at Butler College has for thirty years followed the general plan indicated above. During the latter half of this period the amount of time allotted to principles and physiology has been increased. Other changes have been suggested by Professor Hegner's *College Zoology*, which has been used as a text-book for twelve years. In its present form the course may be outlined as follows: Lectures and laboratory exercises on the structure and functions of the cell are followed by work on the Protozoa. Studies on mitosis, tissues, organs, gametogenesis and general embryology form an introduction to the Metazoa. A series of typical animals, beginning with a simple sponge and ending with the frog, is then studied in the laboratory and lectures. In the latter, particular attention is given to principles, physiology and subjects of general interest. An attempt is made to correlate the lectures and laboratory work. At the end of the course the evidences and factors of organic evolution are briefly reviewed. The course covers two semesters, with four hours of laboratory work and three hours of lectures each week.

This laboratory manual was originally prepared for the zoology course at Butler. The present edition is a revision and enlargement of a private edition which was printed in 1926. Its plan fits it particularly for use with Hegner's *College Zoology*. The manual offers adequate material for a full year's work; for a shorter course the instructor may make a selection according to his convenience or

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preference. Four vertebrates are described, but it is assumed that the frog and dogfish will be more commonly studied, and these have been more fully treated than have the turtle and pigeon.

In the preparation of the manual the author has consulted various authorities. He wishes also to acknowledge his indebtedness to former and present colleagues: to Miss May K. Schaefer and Mrs. Harriet Johnston Calvert, who assisted in the preparation of the first mimeographed edition of the manual; to N. E. Pearson and R. G. Weber, who suggested certain changes during the preparation of the present edition.

H. L. BRUNER.

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INTRODUCTION

LABORATORY EQUIPMENT

1. Microscopes, slides, coverglasses and all necessary zoological materials are furnished by the laboratory.

2. Each student must furnish the following:

A text-book of Zoology
Laboratory Directions in General Zoology
A loose-leaf notebook with side opening, 8 inches x 10½ inches containing drawing paper, and ordinary paper for notes
A case of instruments, which should include a knife, scissors two needles, two pairs of forceps, and a millimeter rule
A hand lens with metal or rubber case
Drawing pencils, 3H, or 4H
A sheet of millimeter paper
A pad of emery paper for sharpening pencils
A paper of pins
Three large Manilla envelopes for laboratory records
A small towel

THE LABORATORY RECORD

The student's laboratory record will include notes and drawings. In the preparation of these, observe the following directions.

General Directions

1. Drawings and notes should be arranged in the order of subjects in the Laboratory Directions.
2. Notes should follow drawings which deal with the same subject.
3. Drawings and notes should not be placed on the same page or sheet.
4. Do not place drawings of different specimens, or notes on different subjects, on the same page.

5. Each page of notes and drawings should have the student's name at the upper right-hand corner.

6. The drawings and notes under each subject or species should have a general heading, with suitable subheads if required by the nature of the record.

Special Directions Concerning Notes

1. Preliminary notes on his observations and experiments should be made in the laboratory by each student, and these should be made the basis for permanent notes which are to be preserved in the laboratory record.

2. Permanent notes should include (a) a summary of observations and experiments made by the student, (b) answers to questions, comparisons, and other information required by the Laboratory Directions, or volunteered by the student himself, (c) general conclusions, if called for.

3. Permanent notes should be written with pen and ink, or with the typewriter.

4. Notes should be numbered if the corresponding drawings are numbered.

Special Directions Concerning Drawings

1. Use a hard pencil, 3H or 4H, for drawings.

2. Drawings should be placed only on the right-hand pages of the open notebook.

3. Do not crowd your drawings; space must be left for labeling.

4. Each drawing should be labeled and numbered as indicated in the Laboratory Directions.

5. All drawings should be line drawings, unless by special arrangement with the instructor. Each line should represent a definite detail of the structure.

Begin your drawing by sketching lightly the outline of the object, using a ruler, if necessary, to get the right proportions. When satisfied with your preliminary sketch, draw the final outlines with a well-sharpened pencil. The light preliminary lines should then be erased.

In case of overlapping structures, draw the upper organs first, then the exposed parts of those which are below. In transparent microscopic objects, the upper and lower parts or organs may be recognized and drawn in their true relations by working downward from the upper surface.

6. Each drawing should be labeled by writing or printing the names of the parts parallel with the upper and lower edges of the sheet. By means of a ruler, draw lines from the names to the parts indicated.

All parts of a drawing should be labeled, even if they have been already named in some earlier drawing.

7. Since the drawings are a record of the laboratory work, they must be made in the laboratory and must not be taken from the laboratory without the permission of the instructor.

8. Keep your finished drawings and notes in a special envelope. At intervals they will be called in for examination and grading. If there are serious errors or omissions the records will be returned to you for corrections. If additional drawings are necessary, they must be made in the laboratory. When your drawings are approved, place them in a special envelope, which should be reserved for approved drawings.

9. The drawings call for certain definite things, and these must be seen before they can be drawn. If you fail to find certain parts after proper effort, leave them out of your drawing and state your reason for doing so. If possible, find time to try again with the assistance of the instructor.

Conditions of Success in Laboratory Work

The success of the student in his laboratory work may depend on many factors, but the final result in the average case must be determined by the student himself. Laboratory knowledge and training cannot be conferred as a gift by instructors or by well-meaning fellow-students. They must be acquired by the learner himself by applying his own powers to the study of real objects. If he fails to acquire them, he will fail to receive the benefits which the course should confer. He will not receive the maximum benefit unless his study awakens many questions which text-book and lectures do not answer.

LABORATORY EXERCISE ON THE USE OF THE MICROSCOPE

1. To each student will be assigned a certain numbered microscope, which should be returned to its place at the end of the laboratory period. Since each microscope is used by several students, each one should leave his instrument in good condition for the next person who may use it. Damage to a microscope should be reported by the person who is responsible; if not so reported the cost of repairs or replacement may be divided among those who use the instrument.

2. The microscope should be carried in such a manner as to prevent injury to the construction. In the majority of the instruments the arm forms a handle for carrying them. All others should be carried by the pillar or base.

3. Each student should become familiar with the following parts of the microscope: the foot, pillar, hinge, arm, stage, mirror, diaphragm, coarse and fine adjustments, tube, draw-tube, low and high-power objectives and eyepieces, and double nosepiece.

Obtain the microscope which has been assigned to you and identify these parts, with the assistance of the instructor.

4. Eyepieces and objectives must be kept clean. Spots on the eyepiece may be located by revolving it as you look through the tube. To clean the lenses use special lens paper, which may be moistened by a drop of water if necessary. Do not touch the lenses unless they need cleaning. If your microscope does not work well after you have followed these directions, call the instructor.

5. **To Obtain the Light.** Place the microscope on the table, with the eyepiece and the low-power objective in position to use. Select a suitable source of light, such as a well-lighted window or lamp. Look through the eyepiece and adjust the mirror so that light from this source will enter the lower end of the tube. The field of the microscope should be evenly lighted and neither too bright nor too dark. Use both sides of the mirror and note the effect of changing from the plane to the concave surface.

6. **Directions for the Study of Transparent Objects.** Biological preparations for the microscope are usually trans-

parent. Such objects may be seen by light which passes through them, and the interior is visible without dissection. For the study of such objects the mirror should be used.

a. *Use of the low-power objective.* Prepare a *slide* as directed by the instructor and place it on the stage of the microscope under the low power. Obtain the light as directed under Section 5. Lower the tube by means of the coarse adjustment until the objective is about one-eighth of an inch from the object. Then look into the tube and focus upward with the coarse adjustment, until you can see the object clearly.

b. *Use of high power.* Before attempting to use the high-power objective, place the part of the object to be examined exactly in the center of the field under low power and focus sharply. Then without changing the focus, revolve the double nosepiece and bring the high-power objective into position. The object should be at least dimly visible. If this is true, use the fine adjustment and focus first upward. If the object disappears, focus downward, until it can be clearly seen. Move the slide, if necessary, and bring the part to be examined into the center of the field. Repeat these operations until you can make the changes easily.

If the object can not be seen after changing objectives, consult the instructor.

Caution. Never attempt to use the high power without first finding the object with the low power, as directed above.

When using high power do not focus downward unless you know the object is in the field of vision and below the focus of the objective.

Do not attempt to use the high-power objective unless the object is covered by a coverglass.

Do not change slides with the high-power objective in position.

7. **Opaque Objects.** Objects that are not transparent can be seen only by light reflected from their surfaces, and only the exterior can be examined. They should be viewed under strong light from a window or lamp. High powers can not be used unless the objects are small. Examine under low power the compound eye of an insect, or other suitable object, as directed by the instructor.

8. **The Size of the Object.** Adjust the draw-tube so as to obtain a tube-length of 160 millimeters. Lay a strip of millimeter paper on the stage and examine it under low power. How large an object can be seen with the combination of lenses which you have? Observe the effect (1) of changing the eyepiece, (2) of changing the draw-tube. Under what conditions can you see the larger object? Examine a demonstration with a micrometer under high power and note the diameter of the visible field in this case.

Record the results of your observations. They can be used for determining the approximate size of larger objects which you will study hereafter.

9. **Inversion of the Image.** With a sharp-pointed pencil, draw an arrow one or two millimeters long on a strip of millimeter paper, and place the arrow under the low-power objective with the point directed away from you. Examine the image carefully, then turn the arrow point toward the right. Make a record of your observations.

10. **Magnification.** Use millimeter paper, as in Section 9, and bring the arrow under low power. Place a millimeter rule on the left side of the stage, close to the objective. Look through the tube with the right eye and at the rule with the other. Adjust the paper and rule and measure the image of the arrow as projected on the rule. Record the result for future use.

The magnifying power of any set of lenses may be determined in a similar way by using as an object a micrometer, in which the millimeter is finely divided. In order to secure uniformity, measurement is made under certain standard conditions, including a tube-length of 160 mm. and an eye-image, or projection, distance of 250 mm. (10 in.).

Magnifying power of the microscope may also be computed by multiplying the magnifying power of the objective by that of the eyepiece. The necessary values will be found on the objectives and eyepieces themselves.

LABORATORY DIRECTIONS IN COLLEGE ZOOLOGY

LABORATORY DIRECTIONS IN COLLEGE ZOOLOGY

CELLS AND PROTOPLASM

The student should be familiar with the important discoveries which have led to the establishment of the "Cell Theory" —especially with the work of Hooke (1665), Dujardin (1835), Schleiden and Schwann (1838-1839), von Mohl (1846), Schulze (1850-1855) and Virchow (1858). The following exercises will introduce the student to the study of cells and protoplasm. Many other examples will be studied as the work advances.

1. Gently scrape the inside of the cheek with a sterilized instrument, as directed by the instructor. Transfer the drop of saliva thus obtained to a clean slide and cover with a coverglass. Under high power observe flat *epithelial cells,* composed of dead *protoplasm.* Each cell includes an outer *cell membrane,* a granular *cytoplasm* which forms the body of the cell, and a *nucleus* which is usually near the center of the cell. These superficial cells die and fall away, as do the outer cells of the skin (epidermis). In both cases new cells are constantly forming to take the place of those that are lost.

Drawing I. Show two or three isolated cells with cell membrane, cytoplasm and nucleus. Make drawings about one inch in diameter.

2. Examine a stained preparation of the blood of a frog or reptile. The most numerous cells are red corpuscles, which give the natural color to the blood. Their color in the preparation is due to the stain. The cytoplasm of these cells contains a protein called *hemoglobin,* a special product of the protoplasm which carries oxygen from the respiratory organs to various parts of the body. Estimate the size of the cells.

Drawing II. Show a few blood cells and label the parts as in I.

3. Examine a leaf of the water plant *Elodea* under low power. The cell units are plainly visible. As you proceed, look for evidences of life. The cells are alive. Select a transparent cell and observe under high power (1) the outer wall of cellulose, a special product of the protoplasm; (2) the layer of *cytoplasm* in contact with the cellulose wall; (3) strands of cytoplasm which cross the central part of the cell; (4) *vacuoles* (spaces filled with water) between the strands of protoplasm; (5) the *nucleus,* which may lie almost anywhere within the cytoplasm of the cell; (6) *chloroplasts,* green bodies whose color is due to *chlorophyll.* They are essential organs of nutrition in all green plants, which manufacture *carbohydrates* by *photosynthesis.* Estimate the size of some of the cells under high power. Where is the cell membrane? The parts of the cell may be seen more distinctly if they are stained by running a little iodine under the coverglass.

Obtain a fresh leaf, if necessary, and find a cell which shows movement of the protoplasm. The chloroplasts are carried along by the currents, which may be very irregular and complicated.

Drawing III. Movement of protoplasm in cells of *Elodea.* Show:

(1) cellulose wall
(2) cytoplasm
(3) nucleus
(4) vacuoles
(5) chloroplasts
(6) movement of the protoplasm
(7) parts of adjacent cells

4. Obtain a drop of water containing living one-celled organisms. Under low power some of these may be seen moving about. Use high power and examine them more closely. The protoplasm of many forms produces special processes which are used as organs of locomotion. Try to find examples of these; if you fail, notify the instructor.

Place a drop of iodine solution or methyl green on the slide beside the coverglass and stain some of the organisms. The nuclei should now be visible.

Drawing IV. Show one or two typical forms with nuclei and organs of locomotion.

PROTOZOA

Phylum, Protozoa
Class, Sarcodina
Subclass, Rhizopoda
Order, Lobosa
Genus, *Amoeba*

General Characteristics. Prepare a slide and examine for *Amoeba* as directed by the instructor. If the culture contains a large species, such as *Amoeba proteus,* begin with the low power and use the high power later for details. For small specimens use the high power at once.

An active *Amoeba* is a naked mass of colorless, granular protoplasm, which changes form by pushing out blunt processes called *pseudopodia* or pseudopods. Is your specimen moving? If so, observe how it moves. Are pseudopods formed in different directions at the same time? What are the functions of pseudopods? Estimate the diameter of your *Amoeba.* Make five or six outline drawings at short intervals.

Drawing I. Locomotion and change of form in *Amoeba.*

Structure. *Amoeba* is a one-celled animal, composed of cytoplasm and one or more nuclei. Two structurally different regions are present in the cytoplasm: the *ectoplasm* and the *endoplasm.* The ectoplasm is the outer transparent layer of apparently homogeneous protoplasm. It is denser and less active than the endoplasm. The external layer of the ectoplasm acts as a cell membrane, which regulates the exchanges between the protoplasm and the external medium. What is the importance of such regulation?

The *endoplasm* is not sharply separated from the ectoplasm but is easily recognized because of the numerous granules which it contains. Note the movements of the endoplasm which accompany the protrusion and retraction of the pseudopods.

Within the endoplasm, identify the following structures:

1. The *nucleus* is a dense granular body, which may be concealed by the other contents of the endoplasm. Examine a demonstration slide if necessary. More than one nucleus may be present.

2. The *contractile vacuole,* when fully formed, is a spherical space filled with watery fluid which is received from the surrounding protoplasm and then discharged through an opening in the ectoplasm. Try to observe the formation of the vacuole and note the interval between successive contractions. *Amoeba* may have more than one contractile vacuole.

3. *Food vacuoles* contain food particles and a drop of liquid. What is the function of the liquid? Can you discover evidence of the digestion of food in the vacuoles?

DRAWING II. The structure of *Amoeba.* Label

(1) pseudopodia
(2) ectoplasm
(3) endoplasm
(4) contractile vacuole
(5) nucleus
(6) food vacuoles

Physiology. *Respiration,* which includes the taking in of oxygen and elimination of carbon dioxide, is a function of the superficial protoplasm. *Excretion* of nitrogenous waste may also occur anywhere on the surface, but such waste is removed largely by the contractile vacuole. The vacuole also assists in respiration by getting rid of carbon dioxide.

Look for *reactions* to stimuli of different kinds. Try to observe the formation of a food vacuole. How does *Amoeba* behave when it comes in contact with a particle of inorganic matter? Do changes in the intensity of the light have any effect on *Amoeba*?

Reproduction. *Amoeba* reproduces asexually in two ways: by binary fission and by sporulation. In *binary fission* two equal cells are formed, each containing one-half of the nucleus and one-half of the cytoplasm of the parent cell. As a preparation for *sporulation, Amoeba* forms a thick external covering called a *cyst,* after which the protoplasm divides into numerous small *Amoebae.* These are set free by the rupture of the cyst.

Phylum, PROTOZOA
Class, SARCODINA
Subclass, RHIZOPODA
Order, LOBOSA
Genus, *Arcella*

General Characteristics. *Arcella* is an amoeboid animal with a shell of chitin which is produced by the protoplasm. The shells of different specimens vary from transparent to dark brown, according to age. The transparent shells are new shells produced by naked individuals, which may be formed either by binary fission or after sporulation. Conjugating and dividing specimens should be looked for.

Structure. Examine several specimens and determine the shape of the shell. On its concave surface, observe a circular opening through which the pseudopods may be extruded. If the shell is transparent, the opening may be seen from the convex side. Under high power the shell shows minute hexagonal areas arranged in a definite pattern.

The *pseudopodia* are transparent, finger-like projections, which will be found in active specimens only. The protoplasm within the shell is attached to the shell by delicate threads. *Two nuclei* are present, usually in opposite parts of the cytoplasm. *Contractile vacuoles* and *food vacuoles* may be numerous. *Gas vacuoles,* which are absent in *Amoeba,* may be present in *Arcella.* What is the greatest diameter of a typical *Arcella*?

DRAWING I. From the convex side (omitting sculpture of shell):

(1) the shell and its opening
(2) protoplasm and pseudopods
(3) nuclei
(4) contractile vacuoles
(5) food vacuoles
(6) gas vacuoles

DRAWING II. Oblique view, showing concave surface and details of shell.

DRAWING III. The sculpture of the shell under high power.

Phylum, Protozoa
Class, Sarcodina
Subclass, Rhizopoda
Order, Foraminifera
Genus, *Globigerina*

Globigerina is a marine protozoan that secretes a many-chambered shell of carbonate of lime. The compartments are connected internally by large openings, and the last chamber has a large external opening. In what order are the several chambers formed? What is the advantage of such a shell? Compare the shell of *Arcella*.

Only dead shells are available for study. They are not covered and should be examined with low power only. Find a perfect shell and note the different compartments and the large opening in the last one.

Examine demonstration slides under the binocular microscope. Find the numerous small openings, *foramina*, through which slender thread-like pseudopods protrude in the living animal. Larger pseudopods extend from the large opening of the last compartment. How does the animal carry on respiration, etc.? Explain the process of shell formation. Is there a similar process in higher animals? What is *Globigerina* ooze? See text-books.

Drawing I. A perfect shell.

Drawing II. The foramina (best seen in a shell fragment).

Phylum, Protozoa
Class, Mastigophora
Subclass, Phytomastigina
Euglena viridis

General Characteristics. Examine first under low power, then find a quiet specimen and study it under high power. The characteristic spindle shape may be altered by squirming movements which are so typical of the organism that they are known as "euglenoid movements." Watch one specimen

closely as it swims, noting that it travels a somewhat spiral course rather than a more direct straight one. Observe the green color.

Structure. From the blunter end of the body extends a long whip-like process, the *flagellum*. It is the organ of locomotion, and works like a screw, pulling the animal after it. The flagellum may be more readily seen by oblique light, or if the diaphragm of the microscope is partly closed. At the base of the flagellum is a small pit, the so-called *gullet,* into which opens the *reservoir,* a spherical sac near the gullet. Small contractile vacuoles open into the reservoir, but they are not easily seen. Near the reservoir is a conspicuous *stigma,* or eyespot, which is probably sensitive to light. The body is covered by a transparent *cuticle,* within which lies the colorless *ectoplasm.* The *endoplasm* contains *chloroplasts* and a *nucleus,* but the latter can not always be seen in living specimens. Examine a stained *Euglena,* if necessary. Oval *paramylum bodies,* consisting of stored food material, are sometimes found in the cytoplasm.

Specimens of resting *Euglena,* enclosed in spherical cysts, may be present in the cultures. Such individuals may divide within the cyst.

What does the presence of chlorophyl suggest as to the mode of nutrition of *Euglena*? Is this the only method? What is the significance of phototropism in *Euglena*?

DRAWING I. Outline drawings showing changes of form.

DRAWING II. A detail drawing. Show:

(1) cuticle
(2) ectoplasm
(3) endoplasm
(4) nucleus
(5) chloroplasts
(6) plastids, if present
(7) stigma
(8) reservoir
(9) gullet
(10) flagellum

DRAWING III. Drawing from stained slide. Show:

(1) nucleus
(2) flagellum

Volvox

General Structure. *Volvox* may be studied by means of prepared slides, but living material should be used if it is avail-

able. Examine the slides with low power only, unless you are directed to do otherwise.

This colonial organism has the form of a hollow sphere, the wall of which consists of a single layer of cells embedded in transparent jelly. The most numerous cells of the colony are the small *somatic cells,* which are joined together by slender strands of protoplasm. Examine them in demonstrations under high power. The cells have also chloroplasts, a contractile vacuole, an eyespot and a pair of flagella, but these details are not easily seen in preserved material.

Reproduction. Both sexual and asexual reproduction occur in *Volvox.* In asexual reproduction certain somatic cells are enlarged to form *parthenogonidia,* ten or twelve of which may be formed in a single colony. The parthenogonidia divide to form many-celled bodies, which pass into the central cavity of the mother colony. Here they form *daughter colonies* which are finally released by rupture of the parent. Look for different stages in the development of these young colonies from the parthenogonidia.

Sexual reproduction. Eggs and sperms may be found in the same colony or in different colonies. Both arise from special somatic cells. The eggs become greatly enlarged before fertilization occurs; after fertilization the zygote is encased in a thick, spiny envelope and enters upon a resting stage. If sexual reproduction occurs in the fall, the zygotes survive the winter and produce new colonies in the spring.

The *sperms* are formed by repeated division of enlarged somatic cells, each one of which may produce a bundle of about 128 flagellate gametes. Find different stages in the development of the sperms. What is the maximum number of sperms in a single colony in your slide? Sperms may fertilize eggs in the same colony or in different colonies.

Is your *Volvox* monoecious or dioecious?

Is *Volvox* a plant or an animal? Give reasons for placing *Volvox* among the Protozoa.

Drawing I. The entire sphere with daughter colonies.

In a part of the sphere show the somatic cells with their protoplasmic connectives and jelly envelopes.

DRAWING II. The entire sphere with eggs and packets of sperms.

DRAWING III. Mature zygotes.

Phylum, PROTOZOA
Class, INFUSORIA
Subclass, CILIATA
Order, HOLOTRICHA
Paramoecium caudatum

General Characteristics. Animals of this species may be seen with the naked eye as oval specks darting through the water. They are usually near the surface, because the bacteria on which they feed are more abundant there, and because the water near the surface has a better supply of oxygen. Keep the slide supplied with water from the specimen jar, and if necessary support the coverglass so that the animals may have room in which to move.

Under low power, study the form and movements and compare these with the form and movements of *Amoeba*. *Paramoecium* has an anterior end which usually goes forward when the animal moves. In the anterior half of the body, observe an oblique longitudinal depression, which becomes deeper toward the middle of the body. This is the *oral groove,* which leads at its posterior end into the *mouth*. The groove lies on the *oral* side of the body; the opposite side is *aboral*. If the animal is transparent, the groove can be seen in any position. Make the following drawing:

DRAWING I. A series of outline sketches, showing the animal with oral groove in different positions.

Structure. Use low power except for details which may call for high power. The permanent form of the animal is due to the presence of an external *cuticle,* which is a product of the cytoplasm. Under the cuticle the cytoplasm shows a layer of non-granular *ectoplasm,* which surrounds a more fluid, granular *endoplasm*. Projecting through the cuticle are numerous slender processes of the ectoplasm, the *cilia,* which are uniformly distributed over the whole body. What are the functions of the cilia?

Observe a specimen at rest and measure it. Find two *contractile vacuoles* and note their alternate contraction and expansion. Radiating canals receive fluid from the adjacent protoplasm and discharge it into the vacuole. As the vacuole increases in size, these canals disappear. The contractile vacuoles discharge by definite openings through the cuticle and ectoplasm to the outside. Look for food vacuoles.

Observe the ectoplasm under high power and note the long oval bodies regularly arranged just underneath the cuticle. These are *trichocysts*. Stain with methyl green and look for a specimen showing a network of small threads on the surface. The threads are formed by explosion of the trichocysts. What is their function? The large *macronucleus* of the organism also takes the green stain and can be readily seen. The smaller *micronucleus* may be seen in demonstration slides. It is usually found very near the macronucleus. Conjugating individuals and specimens undergoing binary fission may also be present in your preparation. If not, find them in demonstration slides.

Obtain a fresh mount and add a little powdered carmine suspended in water. The colored particles will be swept down the gullet into the endoplasm, as are the food particles. Watch a quiet specimen and follow the course of the carmine particles.

DRAWING II. Minute structure. Label:

(1) cilia
(2) ectoplasm
(3) endoplasm
(4) oral groove
(5) gullet
(6) trichocysts
(7) contractile vacuoles
(8) spindle-shaped spaces radiating from vacuoles
(9) food vacuoles
(10) macronucleus, if visible in unstained specimen

DRAWING III. Make two or three sketches to show alternate action of the contractile vacuoles and their spindle-shaped canals.

DRAWING IV. Stained specimen showing:

(1) trichocysts
(2) macronucleus
(3) micronucleus

DRAWING V. Organisms undergoing binary fission.

DRAWING VI. Conjugating individuals.

Order, Peritricha

Vorticella

General Form. *Vorticella* has a bell-shaped body with a long contractile stalk by which the animal attaches itself to some foreign object. The margin of the bell is the *peristome,* which surrounds a more or less elevated area, the *disk.* Between the disk and peristome is the *vestibule* which leads through a *gullet* into the interior. The peristome, vestibule and the margin of the disk are ciliated. Note that the peristome closes over the disk when the stalk contracts.

Structure. The outer layer of the cell is a thin *cuticle* which covers the *ectoplasm.* Inside of the latter is the *endoplasm,* which contains a U-shaped *macronucleus,* a *micronucleus,* a *contractile vacuole,* and *food vacuoles.* Study the formation of food vacuoles by using powdered carmine. The stalk contains a spiral thread, or *myoneme,* whose contraction throws the stalk into a close spiral. Look for free-swimming individuals with a ring of cilia about the narrow aboral end of the bell. *Vorticella* reproduces by fission and also sexually by *microgametes* and *macrogametes.*

Drawing I. Show the entire animal and label the parts observed.

INTRODUCTION TO THE METAZOA

MITOSIS

Cells usually divide by a process called mitosis. Various stages of mitosis will be found in the sections of *Ascaris* and the crayfish which are used in this study. Look for typical stages and draw them.

1. The resting stage, with chromatin granules apparently scattered irregularly through the linin network.
2. Early prophase, with spireme and early stage of spindle formation.
3. Late prophase, showing the mitotic spindle fully formed, and undivided chromosomes.
4. Metaphase, the chromosomes separating.
5. Anaphase, the chromosomes are approaching the poles of the spindle.
6. Telophase, division of cytoplasm and organization of two daughter nuclei.

What seems to be the end result of mitosis? What is the importance of the resting stage?

DRAWING I. Mitosis in the testis of the crayfish. Show at least five typical stages.

DRAWING II. Mitosis in segmenting eggs of *Ascaris*. Draw five or six stages from *Ascaris* and show the number of chromosomes.

THE TISSUES

In the Protozoa the cells formed by division usually separate and form distinct individuals, but in some species the new cells remain in contact with each other and by further division give rise to a colony. Division of labor in such a colony may result in the production of germ cells and somatic cells, but the somatic cells do not form tissues. Metazoa have somatic cells and germ cells, and in addition, the somatic cells undergo differentiation to form tissues.

Four groups of tissues are found in the Metazoa: epithelium, muscular tissue, supporting tissue and nervous tissue.

Epithelium. Recall the definition of an epithelium. Study the epithelial lining of the frog's stomach. Such an epithelium absorbs the digested food. What is absorption? How may epithelium vary in structure?

DRAWING I. Show a few epithelial cells with their nuclei. Indicate the free ends of the cells.

Muscular Tissue. 1. *Smooth involuntary muscle.* Examine a transverse section of the frog's stomach and find the thick circular layer of smooth muscle cells. Use high power and note the shape of the cells and the position of their nuclei. Demonstration slides should be examined if necessary.

DRAWING II. a. Isolated muscle cells. b. A part of the circular layer, showing the relation of the muscle cells to each other.

2. *Striated voluntary muscle.* Study prepared sections of the cat's tongue or other material which shows both transverse and longitudinal sections of striated muscular tissue. The unit of structure in voluntary muscle is a *syncytium* which has the form of a long fiber. Separate fibers are bound together into bundles by connective tissue. Observe the several *nuclei* in the longer fibers, or parts of fibers; the transverse *striations* of the cytoplasm; and the outer covering, or *sarcolemma,* of the individual fiber. Longitudinal lines due to the presence of *fibrillae* in the cytoplasm may sometimes be seen in the fibers.

DRAWING III. The structure of voluntary striated muscle. Show both side view and transverse sections of the fibers.

Supporting Tissue. 1. *Connective tissue* in the submucous layer of the frog's stomach. Note the scattered cells, and the intercellular substance, consisting of a delicate network of fibers. Blood vessels may also be found.

DRAWING IV. Use high power and show details.

2. *Cartilage.* The cells lie in spaces, called lacunae, in the apparently structureless matrix, or intercellular substance.

DRAWING V. Show details under high power.

Nervous Tissue. 1. Isolated neurones from the spinal cord of a vertebrate (smear preparation). Observe the cell bodies and the long processes. How long may the processes be in man?

DRAWING VI. A neurone and its processes.

2. Neurones as shown in sections of the spinal cord of vertebrates. Locate the neurones in the "gray matter" of the cord; a thick layer of fibers, or "white matter," surrounds the gray matter. Some of the large neurones may show axones running out into the white matter.

DRAWING VII. Show one-half of the spinal cord with the neurones and their processes. Label all parts.

3. Nerve cells from the cerebral cortex of a mammal. The axone extends from the deeper end of the cells. The dendrites are numerous. Observe the shape of the cells which are most numerous. They are called pyramid cells.

DRAWING VIII. Pyramid cells from the cerebral cortex of a mammal.

A STUDY OF REPRODUCTIVE ORGANS

As examples of organs we shall study the gonads, or reproductive organs, of a mammal. Since the function of these organs is to produce germ cells, the latter form the *essential part* of the organ, while the somatic cells form the *accessory* tissues.

The Ovary. Study the ovary under low power. The outer layer is the *germinal epithelium*. During embryonic life the primitive ova arise from this layer. The frame work of the ovary is connective tissue, which forms a dense layer under the germinal epithelium and around the larger follicles. Numerous small ova are enclosed in the connective tissue near the surface. Ova in various stages of growth may also be seen. The largest eggs are found in the *Graafian follicles* which are described below. Blood vessels are abundant in the deeper part of the ovary.

Under high power it will be seen that the young ova are enclosed by a single layer of *follicle cells;* these supply nourishment to the eggs. When the egg enlarges during the late oogo-

nium stage, the number of layers of follicle cells increases. Finally a cavity, the *follicular cavity,* is formed between the layers of follicle cells, and the egg, still surrounded by a few follicle cells, becomes attached to the wall of the cavity. Such a mature follicle, called a *Graafian follicle,* moves to the surface of the ovary and discharges its egg, together with the follicular fluid, which aids in carrying the egg into the mouth of the oviduct. The discharge of the egg from the ovary is called *ovulation.* Maturation of the egg begins in the ovary and is completed only after fertilization, which usually occurs in the oviduct.

After ovulation the empty follicle is gradually filled by connective tissue and enlarged follicle cells which produce a yellow pigment. The entire mass of cells and connective is the *corpus luteum.*

Drawing I. The ovary, with young and mature (Graafian) follicles. Label the parts observed.

The Testis. The testis is covered by a layer of flat epithelium cells. Under the epithelium is a dense layer of connective tissue, from which numerous connective tissue septa extend into the interior of the organ and divide it into pyramidal *lobules.* The apices of these lobules are directed toward a thickening of the external connective tissue, called the *mediastinum.* The framework of the testis forms a support for a system of tubules, which includes semeniferous tubules and conducting tubules. The *semeniferous tubules* form the greater part of the lobules and produce the sperms. In the apices of the lobules, the semeniferous tubules lose their germinal epithelium and become mere *conducting tubules,* which pass through the mediastinum to the surface of the testis. Here they emerge from the testis as *vasa efferentia,* which unite to form the *vas deferens.* The vasa efferentia and the adjacent part of the vas deferens compose the *epididymis,* which is closely applied to the surface of the testis.

Various stages in the development of the sperms may be found in the semeniferous tubules. Examine different tubules under high power and identify *spermatogonia,* which lie near the outer wall of the tubules; *spermatocytes,* which lie some-

what nearer the center of the tubule; *spermatids,* which show their character by the excentric position of the nucleus; *sperms,* with a head containing the nucleus, and a tail which is formed by the cytoplasm of the cell.

Mature sperms may be found also outside of the testis in the vasa efferentia.

Drawing II. A diagram of the entire testis. Label the parts observed.

Drawing III. A part of semeniferous tubule showing stages of spermatogenesis.

Living Spermatozoa. Examine living spermatozoa obtained by teasing a small bit of the testis of a rat or frog in normal salt solution. Study their movements, then stain the sperms and observe their structure.

Maturation and Fertilization of the Egg of Ascaris

Examine demonstration slides of *Ascaris megalocephala,* variety *bivalens,* as directed by the instructor.

Fertilization. Fertilization occurs before maturation of the egg begins and the two processes may be studied together. The sperms are short, club-shaped bodies with the nucleus at the broad end, which is surrounded by clear cytoplasm. Pseudopods formed by the cytoplasm are the organs of locomotion. Behind the nucleus is a *refractive body,* which is deeply stained in the preparations. Various steps in the entrance of the sperm may be seen. When it reaches the center of the egg, the sperm loses its sharp outline and awaits the maturation of the egg nucleus which has moved toward the surface of the cytoplasm. Here two successive mitoses occur in quick succession, the two polar bodies being formed.

Maturation. To understand the chromosome changes the following facts must be kept in mind: (a) There are four chromosomes in the oogonia of this variety of *Ascaris.* (b) These chromosomes split in the first oocyte, the halves, or *chromatids,* remaining in contact with each other. (c) The split chromosomes then unite in pairs (synapsis), as a result of which two *tetrads* are formed, each with four chromatids. Two chromatids from each tetrad pass into the first polar body and

the same number remains in the egg, which now contains two *dyads*. During the formation of the second polar body, one chromatid from each dyad passes out of the egg, and two remain to form the chromosomes of the mature egg. When tetrads are formed it may be impossible to distinguish *reduction division* from ordinary *equational* division. The former might apparently occur at either stage of the maturation process.

After maturation, the egg nucleus returns to the center of the cytoplasm. A resting period follows in which egg and sperm nuclei are surrounded by definite nuclear membranes. Later these membranes disappear, a spindle is formed, four chromosomes, two male and two female, take their place in the equator of the spindle and the egg enters upon the stage of segmentation with the somatic number of chromosomes.

DRAWING IV. Sperms of *Ascaris*. These may be found in the uterus between the eggs.

DRAWING V. Maturation and fertilization of the egg of *Ascaris*.

(1) First oocyte, an egg with two tetrads in the cytoplasm near the surface of the egg.
(2) The first polar body with two dyads. The egg, or second oocyte, retains the same number.
(3) Mature egg with second polar body, each containing a dyad.
(4) The resting condition, egg and sperm nuclei with membranes.
(5) In a later stage, two chromosomes may be seen in each nucleus.

GENERAL EMBRYOLOGY

Only the early stages of development will be studied. These occur in all cases of typical development. The sea-urchin will be used as an example, because the eggs are small and the development is easily followed. Study the following stages and draw:

DRAWING I. Segmentation. Two, four, eight-celled stages will be easily recognized. Later stages should also be shown.

DRAWING II. The blastula, with a single layer of cells surrounding a segmentation cavity.

DRAWING III. The gastrula. Early and late stages should be shown. In the older embryos the archenteron is narrow. Label: ectoderm, endoderm, archenteron, blastopore.

DRAWING IV. Older gastrulae will show cells between ectoderm and endoderm. These are mesoderm cells. What is their origin? Find such a gastrula and draw it.

Ectoderm, endoderm and mesoderm are called *germ layers.* Animals which have only ectoderm and endoderm are *diploblastic animals,* those having three germ layers are *triploblastic.*

PORIFERA

Phylum, Porifera
Class, Calcarea
Grantia ciliata

Appearance. *Grantia* is a simple sponge, with one large excurrent opening, *the osculum,* and many incurrent pores scattered over the surface. The closed end of the sac-like body is attached to some external object. Spicules of carbonate of lime project everywhere on the surface and form a conspicuous ring around the osculum. Internally they form a supporting skeleton. Examine a small group of sponges which are attached together. What may be the significance of this attachment?

Drawing I. External view, showing attachment, osculum, etc.

General Structure. Study a specimen which has been split lengthwise through the osculum. This opening leads into a large space, *the cloaca,* which is enclosed by thick walls containing two kinds of canals. The *incurrent* canals open on the external surface and provide for the entrance of water. *Radial canals* open into the cloaca through wide mouths called *apopyles*. Numerous small openings, *prosopyles,* connect radial and incurrent canals. They should be looked for in the slides. Consult text-books.

Drawing II. A longitudinal section, showing cloaca, apopyles, radial canals, incurrent canals.

Microscopic Structure. Obtain a prepared slide and study a cross-section of the wall of the sponge. Three layers can be recognized.

1. The *dermal epithelium,* a single layer of flat cells, covers the external surface and lines the incurrent canals.

2. The *gastral epithelium* lines the cloaca and the radial canals. In the former it is a simple pavement epithelium; in the canals it consists of a layer of collar cells, or *choanocytes,*

which are the nutritive cells of the sponge. Look for the flagella and collars.

3. The *mesogloea,* which lies between dermal epithelium and the gastral epithelium, is a gelatinous layer which contains cells of different kinds, and spicules. Among the cells are numerous small amoeboid wandering cells, scleroblasts which produce the spicules, and reproductive cells. Large unsegmented eggs may be seen. Segmented eggs and early embryos may also be found.

Examine also a tangential section and identify the canals and different cell layers mentioned above.

Drawing III. Show part of a cross-section, with dermal epithelium, choanocytes, mesogloea, spicules, reproductive cells, lining of the cloaca.

Drawing IV. A tangential section, showing canals, their epithelia, the mesogloea and its contents.

Physiology. The canal system and cloaca of the sponge provide for the circulation of water which brings in food and oxygen, and carries out carbon dioxide and nitrogenous waste. Food is seized and digested by the individual choanocyte cells. This is *intracellular digestion.* The flagella of the choanocytes also create the currents which bring in the food, etc. The openings of the body may be closed by special *muscle cells.* What is the importance of this fact? How are commercial sponges propagated?

COELENTERATA

Phylum, Coelenterata
Class, Hydrozoa
Order, Anthomedusae
Genus, *Hydra*

General Structure and Behavior. Observe specimens of *Hydra* in aquarium jars, then obtain one in a watch glass and study it with a hand lens. If the animal is attached, note the tentacles at the free end. How many tentacles do you find? The tentacles surround an elevated area, the *hypostome,* in the *center* of which is the *mouth.* Hydra has radial symmetry. Look for *buds* which may be formed by evagination of the wall of the body. They finally produce tentacles and break away to form separate individuals. Small swellings of the body wall may be *gonads.* Testes are formed near the tentacles, ovaries below the testes.

Observe the changes of form in your animal. If it is extended, note the effect of tapping on the watch glass. Offer to your *Hydra* small bits of snail flesh. Is the animal stimulated by the food before the tentacles touch it? Add to your watch glass a little water containing small free-swimming animals. How does *Hydra* capture such forms? What is the importance of radial symmetry in a fixed animal?

Note the color of your *Hydra.* Two species may be found in the cultures: a green species, *Hydra viridis,* and a brown species, *Hydra vulgaris.*

Drawing I. Make several outline sketches under low power, showing the changes in shape of the *Hydra.*

Microscopic Structure. Place the watch glass containing the specimen on the stage of the microscope. Examine under low power, being careful not to get the objective in the water. Focus carefully and notice that the body and tentacles are

hollow. The internal cavity is known as the *gastro-vascular cavity.* Its only opening is the mouth. In the wall surrounding the cavity may be seen two layers of cells: the outer *ectoderm* which is thin and transparent, and the inner *endoderm* which is somewhat opaque. The green color of *Hydra viridis* is due to the presence of small unicellular plants (*Zoochlorella*) which live in the endoderm cells. This is an example of *symbiosis,* in which two different species live together for their mutual benefit. The ectoderm of the tentacles shows numerous swellings, which are due to the presence of nematocysts.

DRAWING II. Show details of living specimen as seen under low power, including:

(1) gastro-vascular cavity
(2) ectoderm
(3) endoderm
(4) tentacles
(5) hypostome
(6) mouth

Nematocysts. Place your specimen in a drop of water on a slide and cover it, using small bits of paper to prevent the coverglass from crushing the specimen. Observe under low power. Tap gently on the coverglass and look for stinging cells or *nematocysts,* which may be discharged from their containing cells, the *cnidoblasts.* The *cnidocil* is a small thread-like projection of the cnidoblast. It receives the stimulus which causes the cnidoblast to discharge its nematocyst.

Stain your specimen with dilute methyl green. As the stain stimulates the animal, more nematocysts will be discharged. Observe these under high power. In the discharged nematocyst a long slender thread with barbs near its base is seen projecting from a bulb-like capsule. In the undischarged condition, the thread is coiled up within the capsule. Understand from lectures and texts the mechanism for discharging the nematocyst. Look for smaller barbless nematocysts.

DRAWING III. Nematocysts under high power. Show:

(1) cnidoblasts with undischarged nematocysts
(2) a nematocyst discharged from its cnidoblast

Cross-section. Obtain a permanent slide with a cross-section of *Hydra.* Examine under high power. The gastro-vascular cavity, endoderm, and ectoderm are readily identified. Note

the thin layer of non-cellular *mesogloea* between the ectoderm and endoderm. Examine the endoderm cells closely. They are large, irregular epithelial cells with vacuoles and food particles in their cytoplasm. What methods of digestion occur in *Hydra*?

The ectoderm includes four kinds of cells:

1. The *cnidoblasts,* cells which produce nematocysts. They have already been seen in the fresh material.

2. *Epithelio-muscular cells.* These are the largest and most easily seen. The muscle processes on their inner ends run lengthwise. They may show as a circle of dots next to the mesogloea.

3. *Interstitial cells,* small cells packed in groups between the epithelio-muscular cells. These cells give rise to the reproductive cells and cnidoblasts.

4. *Nerve cells.* These cannot be distinguished from other ectoderm cells in your cross section. Examine a demonstration of an entire specimen stained especially to show the cells of the *nerve net.*

The *gonads* should be studied if they are present in the sections. The *ovary* contains one or more large ova, which are covered by the ectoderm. The *spermary,* or testis, may show many mature or developing sperms. Both eggs and sperms arise from the interstitial cells of the ectoderm.

DRAWING IV. Cross-section. Show the parts identified:

(1) ectoderm
(2) endoderm cells
(3) gastro-vascular cavity
(4) epithelio-muscular cells
(5) interstitial cells
(6) mesogloea
(7) ovary
(8) testis

DRAWING V. Examine a demonstration slide and show a part of the nerve net of *Hydra.*

Compare tissues, organs, feeding, digestion, movements of sponges and coelenterates. What is meant by a diploblastic animal? Does the *Hydra* have the power of regeneration? Understand from lectures and your text the life cycle of the *Hydra.* What is the importance of the free-swimming habit of the larva, or *planula*?

Phylum, Coelenterata
Class, Hydrozoa
Order, Leptomedusae
Obelia geniculata

General Characteristics. *Obelia* is a marine hydrozoan which has two stages in its life history: a fixed *hydroid stage,* and a free-swimming *medusa stage.* Such a life history illustrates *alternation of generations,* or metagenesis. Only the hydroid stage of *Obelia* will be studied. The medusa of *Obelia* is small and the medusa of *Gonionemus* will be used as an example of the free-swimming stage.

Obtain a specimen of the hydroid stage of *Obelia* and examine it with a hand lens. Note the root-like, branching *hydrorhiza,* by means of which *Obelia* attaches itself and spreads over the supporting object. From the hydrorhiza arise vertical branches, *hydrocauli,* which bear two kinds of individuals: (1) the feeding individuals, *hydranths,* and (2) reproducing individuals, *gonosomes.* The hydranths are the more numerous.

General Structure. Remove a hydrocaulus from the hydrorhiza and mount on a slide. Examine under low power. If necessary, consult demonstration slides. Note the transparent, non-living covering of the colony, the *perisarc,* which is a product of the ectoderm. It serves as a protection and support. The cup-shaped extension of the perisarc around each hydranth is known as the *hydrotheca.* The gonosome has a similar covering, the *gonotheca.* The hydranths resemble *Hydra* in general structure. Find a fully expanded hydranth, and note the *tentacles,* the *hypostome,* and the *mouth* which leads into the *gastro-vascular cavity* of the hydranth. This cavity is continuous with a canal which runs through the hydrocaulus and hydrorhiza. Thus the entire colony is seen to be a hollow structure nourished entirely by food taken in by the hydranths. The gonosomes serve only as reproductive individuals. Inside of the gonotheca is a hollow stalk, the *blastostyle,* the cavity of which is continuous with that of the hydrocaulus. From the

sides of the blastostyle arise knob-like projections, the *medusa buds*. As they mature, they break away and float out through the opening in the gonotheca as free-swimming individuals.

Alternation of Generations. The hydroid colony of *Obelia* produces hydranths, gonosomes and medusae by budding only. The medusa reproduces by the sexual method, the fertilized egg developing into a stationary hydranth. This in turn produces the colony by budding.

DRAWING I. A sketch of the hydroid colony, showing:

(1) hydrorhiza
(2) hydrocaulus
(3) hydranths
(4) gonosomes

DRAWING II. The hydranth showing:

(1) tentacles
(2) hypostome
(3) mouth
(4) body wall
(5) gastro-vascular cavity
(6) hydrotheca

DRAWING III. The gonosome showing:

(1) gonotheca with its opening
(2) blastostyle
(3) medusa buds

Phylum, COELENTERATA
Class, HYDROZOA
Order, LEPTOMEDUSAE
Genus, *Astrangia*

External Form. *Gonionemus* has a simple hydroid stage, but the life history is not fully known. The medusa is an umbrella-shaped animal with a short handle, or *manubrium*, which bears the mouth at its free end. The concave side of the animal is the *sub-umbrella;* the convex side is the *ex-umbrella.* From the margin of the umbrella arise *tentacles* bearing numerous nematocysts. The *velum,* a circular fold attached to the margin of the umbrella, partly closes the opening of the sub-umbrellar space. Water is forced out of this space by contraction of the velum and margin of the umbrella. In this way the medusa swims. Muscle fibers, derived from ectoderm, are abundant in the velum.

Structure. Since the animal is transparent, the following internal organs can be readily seen. (a) The *stomach* lies in the base of the *manubrium*. Four *radial canals* extend from it to the margin of the umbrella, where they are connected by a *ring canal*. (b) The *gonads* are fluted organs which lie in the ectoderm on the sub-umbrellar side of the radial canals. *Gonionemus* is *dioecious*. Fertilization occurs in the water. (c) Sense organs are of two kinds: large round *visual organs* lie at the bases of the tentacles; smaller, transparent, sac-like organs between the tentacles are *statocysts*, or organs of equilibrium.

DRAWING I. Show a side view, with the near margin of the umbrella elevated, so that the velum may be seen below. Label the following:

(1) velum
(2) manubrium
(3) radial canal
(4) ring canal
(5) gonads
(6) tentacles
(7) visual organs

Phylum, COELENTERATA
Class, ANTHOZOA
Subclass, ZOANTHARIA
Genus, *Metridium*

General Characteristics. *Metridium* has no medusa stage, but the larva (planula) is free-swimming. The polyp creeps very slowly by its basal end; it also changes form greatly. Examine contracted specimens in which the tentacles may be wholly covered. The laboratory specimens have been killed in an expanded condition. Note the fringe of *tentacles* surrounding the *oral disk*, which bears the slit-like *mouth*.

DRAWING I. An oblique lateral view showing the external form. Label the mouth, oral disk, and tentacles. *Metridium* is a sea-anemone.

Structure. Obtain cross-sections for the study of the internal structure. A gullet, or *stomodoeum*, leads from the mouth into the large *gastro-vascular chamber*, into which project numerous septa, or *mesenteries*, from the outer wall. Some of these, called *primary mesenteries*, are also attached to the gullet. How many primary mesenteries do you find? Those attached to the angles of the gullet are called the *directives*.

Observe that the shorter mesenteries vary in length. All mesenteries typically occur in pairs.

Find the *longitudinal muscles* of the mesenteries. What is their function? On the free edges of the mesenteries are the convoluted *mesenterial filaments,* which probably produce digestive enzymes. On each side of the mesentery, close to the filament, may be found a row of small cigar-shaped organs, the *gonads.* From the base of the mesenteries arise the thread-like *acontia,* which are armed with nematocysts. They can be protruded from the mouth and are organs of defense and offense.

Physiology. Food is swept into the mouth by the tentacles and by the cilia which cover the oral disk and the tentacles. Grains of sand are removed from the oral disk by the cilia. *Respiration* is provided for by one or more groove-like *siphonoglyphes,* which begin in the angles of the mouth and continue through the gullet. Cilia which line these grooves keep a current of water flowing into the body and out again.

DRAWING II. A cross-section through the gullet. Label gullet, primary and secondary mesenteries with their muscles, mesenterial filaments, gonads, siphonoglyphes.

DRAWING III. A cross-section below the gullet. Label gastro-vascular cavity and mesenteries.

Phylum, COELENTERATA
Class, ANTHOZOA
Subclass, ZOANTHARIA
Genus, *Astrangia*

Astrangia is a coral which is common in the shallow waters of New England. The hard part of the coral is an *exoskeleton* formed by the ectoderm of the polyps, which lie in the cup-shaped *thecae.* In the dried coral, note the *calcareous septa* which project from the outer wall of the theca toward the center. In the living animal these septa are enclosed by folds of the outer wall of the polyp and are entirely external to it; they do not correspond to the mesenteries. Study also preserved specimens which show the polyps in place.

DRAWING I. The dried coral, showing thecae.

DRAWING II. Preserved specimens with polyps.

PLATYHELMINTHES

Phylum, PLATYHELMINTHES
Class, TURBELLARIA
Order, TRICLADIDA
Genus, *Planaria*

The Living Animal. *Planaria* is a fresh water animal which is common in ponds and sluggish streams. It avoids the light and is found during the day only in shaded places or buried in mud.

Obtain a specimen in a watch glass and study its movements. What is the mode of locomotion? Are cilia present on the surface of the body? *Planaria* has bilateral symmetry. What are some of the advantages of this kind of symmetry? Compare the upper and lower surfaces of the animal. Of what importance are the differences? Find the eyespots. Are other sense organs present?

Add a drop of meat juice to the dish containing living *Planaria* and note any changes in the behavior of the animals. Place a small piece of beef or snail meat in the dish and try to observe the method of feeding. Food is taken by means of a tubular pharynx which is pushed out through the mouth, an opening on the ventral surface near the middle of the body. If the feeding experiment fails, the pharynx may often be seen if *Planaria* is placed in a drop of water on the tip of the finger. How does *Planaria* digest food?

Slide Preparation. Compare the specimen with the living animal, and find (1) the mouth, (2) the pharynx pouch, (3) the retracted pharynx, (4) the three-branched digestive sac, which joins the anterior end of the pharynx. Note the position of the three branches and the secondary diverticula which arise from them. By branching, the digestive sac distributes the food which it digests. The *reproductive pore* behind the mouth is the opening of the genital cloaca, into which open both male

and female reproductive organs. In transparent specimens the brain may be seen between the eyespots.

Planaria is a triploblastic animal. The ectoderm is the somewhat transparent layer which covers the surface of the body; endoderm lines the digestive tract; mesoderm fills the space between ectoderm and endoderm. There is no coelom.

Regeneration. *Planaria,* like *Hydra,* has a remarkable capacity for reproducing lost parts. If time permits, regeneration experiments may be attempted under the direction of the instructor.

Read text-books for additional details of internal organs and sexual reproduction of planarians.

Drawing I. The living animal. Show dorsal and ventral surfaces, the mouth and reproductive pore.

Drawing II. The mounted specimen. Show digestive tract, eyespots and brain.

Phylum, Platyhelminthes
Class, Cestoda
The Tapeworms

Life History. Tapeworms are greatly modified internal parasites, which have two different stages in the life history: the bladder-worm, or *cysticercus,* which occurs in the tissues, and the *sexually mature animal* which lives in the alimentary canal. These two stages usually occur in different hosts. The adults live only in vertebrates, which are the *final hosts;* the cysticercus occurs in the *intermediate host,* which may be a vertebrate or an invertebrate.

The Adult Tapeworm

Two different species are described below. Either *Taenia crassicollis* or *Dipylidium caninum* may be used but *Taenia* may be shown only under demonstration microscopes.

Taenia crassicollis. The adult lives in the cat; the bladder worm, in rats and mice. The adult may reach a length of 60 cm. The body includes the head or scolex which bears a ter-

minal circle of hooks and four lateral suckers. Behind the head is the neck from which arise the segments or proglottids. These increase in size toward the posterior end, the last segment being the oldest. Two longitudinal excretory canals may be easily seen. They are connected by a cross canal at the posterior end of each segment. A longitudinal nerve lies near each longitudinal canal. No digestive organs are present.

Reproductive organs, both male and female, are present in each segment. Both systems open into a common genital pore which lies in the margin of the proglottid. Male organs include (1) a penis, (2) a vas deferens, (3) numerous testes which are scattered through the segment. Female organs include (1) the vagina, which opens at the reproductive pore, (2) an ootype, where the egg shell is formed, (3) a two-lobed ovary, (4) a yolk gland, which lies in the posterior end of the segment, and (5) a uterus, in which the eggs begin their development. The sperms are transferred to the vagina by the penis, but cross-fertilization may occur. The yolk gland furnishes yolk cells, which are inclosed in the egg shell with the egg. The ootype lies near the median line of the segment and in the center of the female reproductive system.

Compare different segments on your slide; some are young, with immature sex organs; others are more or less filled by the branched uterus. Study an older segment and explain its condition. What eventually becomes of such segments?

Dipylidium caninum. The adult lives in the dog; the bladder stage in the dog flea. The *scolex* has a conical hook-bearing *rostellum,* which can be retracted into a pocket in the end of the scolex. How many suckers are present?

The excretory canals and nerves are like those of *Taenia.* Two genital pores are present in each segment, also two sets of male and female reproductive organs. A vas deferens and a vagina open into each genital pore. Testes are scattered through the entire segment. The vagina leads from the genital pore to the ootype, a small round body which lies between ovary and yolk gland on each side of the segment. The ovary is larger than the yolk gland and lies anterior to the small ootype. The uterus is much branched in *Dipylidium.* The fer-

tilized eggs are set free with the segment. Examine older segments which show various stages of embryonic development.

Drawing I. The scolex and anterior segments. Label the hooks, suckers, neck, and other features which may be visible. Draw either *Taenia* or *Dipylidium.*

Drawing II. A sexually mature segment of *Taenia* or *Dipylidium.* Label the following:

(1) excretory canals
(2) genital pore
(3) testes
(4) vas deferens
(5) vagina
(6) ootype
(7) ovary
(8) yolk gland
(9) uterus (if present)

Drawing III. A ripe segment with branching uterus. Can you find all of the internal organs? Label all the parts which you see.

Study of Sections. Obtain a slide with cross-sections of the mature proglottids of *Taenia.* The segment is composed of ectoderm and mesoderm only. Endoderm is wanting. Near each side of the flattened segment is an excretory canal. Circular muscles form a conspicuous layer parallel with the surface. Longitudinal muscles, which are cut transversely, show as dots outside of the circular layer. Within the latter may be found sections of the uterus containing small eggs, and sections of testes, gland-like organs uniform in size and shape.

Drawing IV. A cross-section of a mature segment of *Taenia saginata,* the beef tapeworm. Label:

(1) longitudinal canals
(2) circular muscles
(3) longitudinal muscles
(4) testes
(5) the uterus with eggs
(6) other organs which may be seen

The Bladder-Worm

Obtain a specimen of beef containing the bladder-worm stage of *Taenia saginata.* Some of the bladders are open and show the heads of the worms. What changes occur after such meat is eaten?

Drawing V. The bladder-worm stage. Show (a) the distribution of bladders in the muscle, and (b) an open bladder containing the head of a worm.

NEMATHELMINTHES

Phylum, NEMATHELMINTHES
Class, NEMATODA
Genus, *Ascaris*

General Characteristics. Round worms of the genus *Ascaris* are common parasites in the intestine of pigs, horses, and man. In the larger species of *Ascaris,* the female may reach sixteen inches in length and about one-fourth of an inch in diameter. The male, which is smaller than the female, can be distinguished by the presence of a bend in the posterior part of the body. Obtain a specimen; is it a male or a female?

The *mouth,* which is bordered by one dorsal and two ventral *lips,* is located at the anterior end; the *anus,* near the posterior end. In the male, a pair of needle-like chitinoid bodies, the *penial setae,* may project from the anus, which is used as a genital opening. The female reproductive organs have a separate external opening.

DRAWING I. An external view of one specimen. Label the parts seen.

Internal Structure. Obtain a slide with a cross-section of *Ascaris.* Use low power and identify the body wall, the alimentary canal, and the coelom.

The *body wall* consists of three layers: (1) an outer, transparent *cuticle,* (2) a layer of *epidermis,* derived from the *ectoderm,* (3) an inner layer of *muscular tissue* derived from the mesoderm. *Ascaris* is triploblastic. In the region of the median dorsal, median ventral, and lateral lines, the ectoderm forms thickenings which project inward and divide the muscle layer into four longitudinal bands.

The *alimentary canal* is a straight tube, which includes the muscular *pharynx,* a long non-muscular *intestine* and a posterior narrow portion, the *rectum,* which opens to the outside through the anus. In the section, which is cut through the intestine, observe that the latter is a thin-walled tube, consist-

ing of a single layer of epithelium (endoderm). The epithelium is bounded internally and externally by a thin cuticle.

Between the alimentary canal and the body wall is a space called the *coelum,* in which lie the reproductive organs.

The *reproductive organs* of the *male* consist of a long, coiled *testis,* the posterior end of which is continuous with the *vas deferens.* This duct expands posteriorly to form the *seminal vesicle* which opens into the *rectum.* Since the testis is coiled, it may appear several times in your section.

The *female reproductive organs* form a Y-shaped system with the arms directed toward the head. The anterior parts of the arms of the Y are the ovaries. Posterior to these is the *uterus,* which opens to the outside through a short tube, the *vagina.* The opening is near the middle of the body, or in the anterior half. The ovaries and uterus are more or less coiled and may appear in the sections more than once.

The excretory organs consist of two longitudinal canals, one in each lateral line. They open to the outside by a single pore in the anterior ventral body wall.

DRAWING II. A cross-section of *Ascaris.* Label the following:

(1) cuticle
(2) ectoderm
(3) dorsal, ventral, lateral lines
(4) muscle layer
(5) alimentary canal
(6) reproductive organs (name definitely)
(7) coelum
(8) excretory canals

Phylum, NEMATHELMINTHES
Class, NEMATODA
Trichinella spiralis

Obtain a prepared slide and examine it for encysted larvae of *Trichinella.*

Trichinella is a minute, parasitic worm that requires two hosts to complete its life history. However, two generations, including adult worms and their young, live in the same host. The adult, or sexually mature animal may be found in the alimentary canal of man, pigs, and rats. The females produce living young which burrow through the intestinal wall and enter

the lymph vessels. Through these they reach the striated muscles. After penetrating the sarcolemma of the muscle fibers, they coil up in the muscle substance. A spindle-shaped cyst develops, which becomes calcified after several months. If flesh of such an infected animal is eaten by another host, the larvae becomes sexually mature in the alimentary canal. How is the worm released from the calcareous cyst, after it reaches the alimentary canal? How may trichinosis be avoided? Does the local or federal government inspect pork for *Trichinella?*

Drawing I. A portion of striated muscle showing one encysted animal in detail.

ECHINODERMATA

Phylum, Echinodermata
Class, Asteroidea
Genus, *Asterias*

The species studied is a common one on the North Atlantic coast. Starfishes are enemies of clams, oysters, snails, and barnacles. The active crustacea, and even vertebrates, may also be captured by them.

External Structure. In a dried specimen observe the two regions of the body: the central *disk* and the *arms*. The mouth lies in the center of the disk on the *oral surface*. The opposite surface is *aboral*. On the oral surface of the arms and disk, find the *ambulacral grooves* which contain the *ambulacral* or *tube feet*. The tube feet are a part of the *water-vascular system*, which opens to the outside through the *madreporic plate*, or *madreporite*, a small convex body on the aboral surface of the disk. Examine the plate with a lens. It acts as a strainer. If some of the tube feet are removed, pores will be seen, through which the feet communicate with the *ampullae*, internal sacks whose contraction causes elongation of the tube feet.

The *outer surface* shows numerous spines which are attached to calcareous plates formed in the somatic mesoderm. The spines on each side of the ambulacral groove are movable. Around the base of the spines small pincer-like bodies, *pedicellariae*, may be seen. In the spaces between the spines are small sac-like organs, the *branchiae*, which open into the coelum through thin places in the body wall.

Drawing I. Using the dried specimen, draw an outline of the body, oral view. Work out details in the disk and one arm. In another arm show the ambulacral skeleton and the pores for the tube feet. Label carefully.

Internal Structure. Examine a formalin or alcoholic specimen from which a part of the aboral wall of the body has been removed, so as to expose the internal organs. The large

stomach, which lies in the disk, may be divided into cardiac and pyloric portions. Into the narrow aboral end open the large digestive glands, or *hepatic caeca,* which extend into the arms. The wide cardiac part of the stomach can be everted through the mouth. Find the small muscles which draw the stomach back into the body. A short intestine opens on the aboral surface of the disk. Explain the slight development of the intestine.

The *water-vascular system* of the starfish includes: (1) the madreporite already mentioned; (2) the stone canal, which leads from the madreporite to (3) a ring canal around the mouth; (4) five radial canals which arise from the ring canal, one for each arm; (5) ampullae and tube feet. The radial canals are connected by short tubes with the ambulacral feet, which are directly continuous with the sac-like ampullae. What are the functions of the tube feet?

The *nervous system* arises from the ectoderm. The central portion includes a nerve ring around the mouth, and five radial nerves which follow the middle of the ambulacral grooves to the tips of the arms. The nerves show through the epidermis in dried specimens. In an alcoholic specimen, eyespots may be found at the tips of the arms.

Two branching *gonads* lie in the proximal part of each arm, one on each side. They open externally in the angles between the arms.

Cut a section of the body wall and observe the calcareous plates of the skeleton and the membranous areas which bear the branchiae. Examine the pedicellariae and branchiae of an alcoholic or formalin specimen under the binocular microscope.

Drawing II. A section of the body wall, showing calcareous plates, spines, pedicellariae and branchiae.

The branchiae are organs of *external respiration,* by means of which carbon dioxide is discharged from the body and oxygen is taken in. A typical circulatory system is wanting. Oxygen is distributed chiefly by the *body fluid* which fills the coelom and the spaces between the cells. The same fluid receives carbon dioxide and nitrogenous waste from the cells. This exchange between the cells and the body fluid is *internal respiration.*

MOLLUSCA

Phylum, Mollusca
Class, Amphineura
Order, Placophora
The Chitons

The *chitons* are primitive Mollusca, in which the characters of the phylum are shown in a simple condition. Note the bilateral symmetry, the large ventral *foot,* and the dorsal *mantle* to which the *plates* of the shell are attached. Observe the overlapping of these plates. What is the advantage of separate plates?

Note the *headfold,* containing the *mouth,* at one end of the elliptical body. The *anus* is at the opposite end. Find the gills on each side, under the edge of the mantle.

Drawing I. A dorsal view showing plates of shell and the mantle.

Drawing II. A ventral view showing:

(1) mouth
(2) headfold
(3) foot
(4) gills
(5) mantle
(6) anus

Phylum, Mollusca
Class, Pelecypoda
The Fresh Water Mussel

External Structure. The mussel is enclosed in a shell consisting of two parts or *valves,* which are hinged together in the *dorsal region* by a tough, elastic *hinge ligament.* If the living animal is placed in fresh water and left undisturbed for a time, the valves will be seen to gap and the *tongue-like foot* may be extruded from the ventral region. When the valves are slightly separated, two openings are visible at the posterior end. These are the openings of the *siphons,* two short tubes which are formed by the mantle. Water passes in and out through the siphons. The ventral siphon is *incurrent,* the dorsal siphon

excurrent. Use carmine, if necessary, to detect the currents which pass through the siphons.

The external surfaces of the valves are marked by a series of concentric ridges, called *lines of growth.* The center of these lines is the *umbo,* which lies near the hinge ligament. The umbo is the oldest part of the shell, the part formed by the young animal. The ridges correspond to intervals of rest between successive periods of growth.

DRAWING I. A surface view of one valve. Label the following:

(1) dorsal region
(2) ventral region
(3) anterior end
(4) posterior end
(5) umbo
(6) lines of growth
(7) dorsal siphon
(8) ventral siphon
(9) foot, if extruded

Internal Structure. The two valves are held together by two large transverse muscles. One of these, near the anterior end, is the *anterior adductor;* the other, near the posterior end, is the *posterior adductor.* Under the direction of the instructor, pry the shell open and hold it open by a wedge between the valves. Note the membranous folds or *lobes,* of the *mantle* which lie in contact with the inner surface of the shell. The space between the two mantle lobes is the *mantle cavity.* Find the *adductor muscles,* then separate the mantle from the left valve and cut the adductor muscles where they are attached to this valve.

The points of attachment of the *adductor muscles* appear as large oval scars in the shell. A smaller scar dorsal from that of the posterior adductor is the point of attachment of the *posterior retractor* of the foot, and a similar impression posterior to the scar of the anterior adductor is the point of attachment of the *anterior retractor* of the foot. A *protractor* of the foot is attached to each valve directly ventral to the scar of the anterior retractor. Do you understand the use of these foot muscles?

The *shell* consists of three layers: (1) The outer, brown *horny layer,* which is secreted by the edge of the mantle, serves to protect the underlying parts from the carbon dioxide in the water. (2) A middle *prismatic layer,* also secreted by

the edge of the mantle, is composed of minute prisms of calcium carbonate. (3) The inner, more or less iridescent layer, is the *mother of pearl.* It is secreted by the whole surface of the mantle. Where does the mussel get material for the manufacture of its shell?

DRAWING II. A view of the mussel with the left valve lifted, the soft parts lying in the right valve, covered by the mantle. Label the following parts:

(1) right lobe of mantle
(2) left lobe of mantle
(3) adductor muscles
(4) foot muscles
(5) the pallial line
(6) the scars of the adductor muscles
(7) scars of foot muscles

The respiratory organs. Remove the left lobe of the mantle without cutting into the siphons, and expose the contents of the mantle cavity, which include a pair of gills on each side, and a median visceral mass and foot.

Each gill consists of two perforated plates, or *lamellae,* which enclose a system of parallel *water tubes.* At the dorsal margin of the gill the tubes open into an *epibranchial* chamber, which in turn opens into the *cloaca*—a cavity which discharges through the excurrent siphon. Split the dorsal margin of the excurrent siphon and find the terminal portion of the *intestine.* The *anus* opens into the cloaca. Four epibranchial chambers open into the anterior end of the cloaca. The ventral surface of each chamber is perforated by the openings of the water tubes of one of the gills. Some of these openings can be seen without dissection. With a microscope, look for cilia on the gills and mantle of the mussel. What are the functions of the cilia?

The digestive organs. Find the mouth at the anterior end of the visceral mass, between two pairs of ciliated flaps, the *labial palps.* A short oesophagus leads to the stomach, which lies in the visceral mass between the lobes of the digestive gland. The intestine forms two loups in the visceral mass, then bends dorsally and passes through the pericardial cavity and the ventricle of the heart. Follow the intestine from the pericardial cavity to the anus. The stomach and anterior part of the intestine may be seen by cutting away the wall of the visceral mass on one side. How does the mussel obtain its food?

The *nervous system* consists of three pairs of ganglia and the

associated nerves. The ganglia of the system are the paired *cerebral ganglia,* which lie dorsal to the mouth and close to the anterior adductor muscle; the two *visceral ganglia,* which lie near together on the ventral surface of the posterior adductor muscle; the paired *pedal ganglia,* which lie in the visceral mass at the dorsal margin of the foot. The cerebral ganglia are connected with the visceral and pedal ganglia by special nerves.

The *circulatory system* includes the heart, blood vessels, and spaces called sinuses which lie between the organs. Identify the pericardium in the dorsal part of the visceral mass. The intestine passes through the ventricle of the heart, which has also an auricle on each side.

The excretory and reproductive systems. Ventral to the pericardium on each side is a brown excretory organ, the *kidney.* The sexes are separate. The testes are large paired glands which lie in the visceral mass posterior to the stomach. The ovaries are located in the same region.

The eggs are fertilized by sperms brought in by the currents of water. After fertilization the eggs enter the water tubes of the gills, which serve as brood chambers. The eggs develop here into bivalve larvae, called *glochidia,* which escape from the parent and attach themselves to the skin or gills of a fish. When they complete their development they fall to the bottom as young mussels. If the gills of your specimen are swollen, the eggs or larvae should be examined. The living glochidia open and close the valves of the shell.

What is the importance of such a parasitic habit in an animal like the mussel?

Drawing III. A view of the internal organs. Label the following:

(1) visceral mass
(2) foot
(3) gills
(4) mouth
(5) labial palps
(6) parts of digestive system
(7) anus
(8) pericardium
(9) gonads
(10) excretory organs

ANNELIDA

Phylum, Annelida
Class, Chaetopoda
Sub-class, Oligochaeta
Order, Macrodrili
Lubricus terrestris

External Characters

Obtain a preserved specimen and identify anterior and posterior ends, dorsal and ventral surfaces. Living specimens should be examined, if possible.

The body is divided into ring-like segments, or *metameres.* Draw the specimen between the fingers and note the short, stiff bristles which protrude from the ventral and lateral surfaces of the body. These are *setae,* which are used in locomotion. Observe with a hand lens the number and position of the setae on the segments. How many longitudinal rows do you find?

Find the *clitellum* in segments 32-37. The body wall is much thicker here than elsewhere, due to the presence of epidermal glands.

The *mouth* is at the anterior end under the *prostomium,* which projects forward from the first segment. The *anus* is a vertical slit in the last segment. On the ventral surface of segment 15 are two conspicuous openings of the *vasa deferentia.* Near them, in segment 14, are the minute openings of the two oviducts. Look for them with a hand lens. Two nephridia open from each segment, except the first three and the last. The openings are difficult to see, even with a hand lens.

Drawing I. Ventral view of the anterior forty segments of a preserved specimen, showing:

(1) prostomium
(2) mouth
(3) setae
(4) openings of oviducts
(5) openings of vasa deferentia
(6) clitellum

Internal Anatomy

Place a preserved animal in a dissecting pan with the ventral side down, and fix it in position with two pins, one at each end of the body. With sharp-pointed scissors make a longitudinal incision near the mid-dorsal line, beginning posterior to the clitellum. Carry the incision forward to the prostomium, and be careful to cut only the body wall. Separate the edges of the body wall and observe the *transverse septa* which connect the body wall with the digestive tract. Carefully cut these septa and pin out the body wall on each side. Slant the pins outward, to obtain room for work.

Coelom and Body Wall. The coelom is a large space between the body wall and the digestive tract. It is divided into compartments by the transverse septa. How are these compartments related to the external segmentation of the body? In the living worm the entire coelomic cavity is filled with colorless fluid.

The *body wall* consists of several layers. The *cuticle* is a non-cellular layer which covers the entire body; it is produced by gland cells of the epidermis. The iridescence of the earthworm is due to the presence of minute striations on the outer surface of the cuticle. The *epidermis* is the outer cell layer of the body. Beneath the epidermis is a thin layer of circular muscle cells, and under these, a thick layer of longitudinal muscle. Other details will be seen in cross-sections.

The Digestive Tract. This is a tube with different parts which perform different functions.

The *oral cavity* lies in segments 1 to 3. The brain rests on its dorsal surface.

The thick-walled *pharynx* in segments 4 and 5 is a sucking organ.

The *oesophagus,* a narrow tube, lies in segments 6 to 14.

The *crop* is a storage organ in segments 15 and 16.

The *gizzard,* or grinding stomach, lies in segments 17 and 18.

The *intestine,* a tube of uniform diameter, extends from segment 19 to the anus. The dorsal wall of the canal is folded in to form the *typhlosole,* which increases the digestive and ab-

sorbing surface. On the coelomic surface of the intestine is a layer of *chlorogogue* cells which are best seen later in the cross-section.

The Circulatory System. This is a system of closed tubes; a central heart is wanting. Capillaries distribute the blood; outside of the capillaries is the lymph, the medium in which the cells live. The red blood contains hemoglobin dissolved in the plasma. The most important vessels are located as follows:

The *dorsal vessel* lies on the dorsal surface of the digestive tube. Some of its larger branches may be seen. Where do they go?

The *subintestinal vessel* lies under the digestive tube. It is best seen in the region of the intestine.

Five pairs of "*hearts*" connect the dorsal vessel with the subintestinal vessel in segments 7 to 11. The hearts and the dorsal vessel have muscular walls by whose contraction the circulation is maintained. Valves prevent a reversal of the current.

A *subneural vessel* and two *lateral neural* vessels are small blood vessels of the ventral nerve cord. They will be seen in cross-sections.

Reproductive Systems. Earthworms are hermaphroditic. Some of the organs are difficult to find on account of their small size.

The female reproductive system. The small ovaries are in the ventral part of segment 13, from which the eggs are carried by oviducts to the external openings in segment 14. *Seminal receptacles,* which receive the sperm by transfer from another worm, are paired sacks in segments 9 and 10. They open only to the exterior.

The male reproductive organs. The paired testes lie in segments 10 and 11. Sperms leave the testes in an immature condition and pass into the large *seminal vesicles,* of which there are three pairs in segments 9, 11 and 12, one pair in each segment. The vasa deferentia open on segment 15.

Read text-book and lecture notes on the details of reproduction.

The Excretory System. Organs of excretion, *nephridia,* are present in each segment except the first three and the last.

They are most easily seen in the region of the intestine. Cover your specimen with water and examine the inner surface of the body wall. The nephridia are whitish tubes attached to the septa and body wall. They lead from the coelom to the surface of the body. The inner opening of the nephridium is the *nephrostome,* the outer opening the *nephridiopore.*

Drawing II. Dorsal view of dissected specimen showing:

(1) septa
(2) coelom
(3) pharynx
(4) oesophagus
(5) crop
(6) gizzard
(7) intestine
(8) seminal receptacles
(9) seminal vesicles
(10) nephridia
(11) clitellum, in wall
(12) brain
(13) hearts
(14) dorsal blood vessel

The Nervous System. Carefully remove the digestive tube from the body, beginning in the region of the intestine and working forward to the pharynx, which should be left in position. The *ventral nerve cord* will now be exposed. Observe the ganglionic enlargement of the cord in each segment and the nerves which run to the body wall on each side. The ventral nerve cord is actually double, a *ladder type system,* but the paired ganglia in each segment behind the fourth are closely bound together in one sheath, and the longitudinal connectives are united in the same way.

The brain and subpharyngeal ganglia. Lift the posterior end of the pharynx and find the paired subpharyngeal ganglia in segment 4 at the anterior end of the ventral nerve cord. From these ganglia arise two nerves, the circumpharyngeal connectives, which run around the pharynx, one on each side, to join the bilobed brain. From the brain, subpharyngeal ganglion, and the circumpharyngeal connectives arise nerves which supply the prostomium and the four anterior segments. In the brain and subpharyngeal ganglia the double character of the nervous system is easily seen.

Text-books may be consulted for other details.

Drawing III. A dorsal view of dissection of nervous system. Show:

(1) brain
(2) circumpharyngeal nerves
(3) subpharyngeal ganglion
(4) ganglia in their segments
(5) nerves connecting ganglia of adjacent segments

Microscopic Structure

Obtain a cross-section through the region of the intestine and note the parts already seen in the gross dissection: body wall, coelom, wall of the intestine, ventral nerve cord and blood vessels. Sections of nephridia and septa may also be found.

1. **The Body Wall.** Five layers may be recognized: a cuticle, the epidermis, circular muscles, longitudinal muscles and somatic peritoneum. Epidermis and cuticle are derived from the *ectoderm*. The other layers are *somatic mesoderm*.

a. The *cuticle* is a non-cellular layer, produced by the cells of the epidermis.

b. The *epidermis* is the outer cell layer of the body. It is composed chiefly of columnar cells, many of which are gland cells. Between the bases of the columnar cells are small rounded cells which probably produce the other cells of the epidermis. Nerve cells are present in the epidermis but they can not be seen in the sections. The gland cells furnish mucus which keeps the surface of the body moist.

c. A layer of *circular muscle* cells lies under the epidermis. In a living earthworm, with the coelomic cavity filled with body fluid, what would be the effect of contraction of this circular muscle layer alone?

d. The *longitudinal muscle* stratum is the most conspicuous layer in the wall of the body. It is divided into longitudinal bands which are separated laterally by the setae. The two dorsal bands are separated in the mid-dorsal line by the peritoneum.

Look for the setae. The muscles which move them are inserted on their inner ends.

e. The *parietal peritoneum* is part of a continuous layer which lines the coelomic cavity. The parietal portion is a single layer of flat epithelial cells.

2. **The Wall of the Intestine.** Four layers may be found.

a. The outer layer is the visceral peritoneum, which is represented by a coat of large, irregular *chlorogogue cells*. Their function is uncertain.

b. A layer of longitudinal muscle fibers is represented by a circle of dots in the cross-section. Use the high power.

c. Circular muscle fibers form a continuous ring; they produce peristaltic movements of the wall of the intestine.

d. The inner lining of the intestine is a ciliated epithelium which yields enzymes and absorbs the digested food. What is the function of the cilia? Note the position of the typhlosole, which takes an important part in the digestion and absorption of food.

The lining epithelium of the intestine is derived from the endoderm; layers a, b and c, from the visceral mesoderm.

3. **The Coelom** lies between the parietal and visceral layers of the mesoderm. It is divided by septa, which may be seen in some of the sections.

4. **Blood Vessels.** The dorsal and subintestinal vessels are easily located. They may also show branches running to the intestine and to the body wall.

The single subneural vessel and the two lateral neural vessels may now be seen in the sheath of the ventral nerve cord. The subneural vessel receives blood from the dorsal vessel.

5. **The Ventral Nerve Cord.** The cord is double, although the component ganglia and connectives are incompletely separated. Conspicuous nerve cells may be seen in the ventral and lateral parts of the cord. In its dorsal half are large longitudinal fibers which connect remote segments of the body.

Drawing IV. A cross-section, showing:

(1) epidermis
(2) circular muscles
(3) longitudinal muscles
(4) setae
(5) coelom
(6) nephridia
(7) ventral nerve cord
(8) dorsal blood vessel
(9) subintestinal blood vessel
(10) subneural blood vessel
(11) wall of digestive tract
(12) typhlosole

General Physiology

1. *Movements.* Obtain a small earthworm and study its movements. Which muscles are used in the contraction and elongation of the body? Explain elongation.

2. *Use of the setae.* Place an earthworm on a glass plate and observe its movements. Place the animal on moist filter paper. How are the setae used in locomotion?

3. *Burrowing.* How does the earthworm make its burrow?

4. *Circulation of the blood.* Examine a small transparent worm. Note the direction of the circulation in the dorsal vessel. The contraction of the hearts in segments 7 to 11 may be seen. Do the walls of the ventral vessel contract?

5. *Respiration.* The epidermis is the organ of *external respiration. Internal respiration* is the respiration of the cells, which are bathed by the lymph.

6. *Reactions.* Touch various parts of the earthworm and try to determine which part is most sensitive to contact. Do you find any special sense organs?

Determine whether the earthworm is sensitive to light by studying the behavior of a specimen in a flat dish that is partly covered.

Record all conclusions in your laboratory notes.

DRAWING V. A sketch of a living specimen, showing blood vessels. Indicate direction of flow of the blood.

ARTHROPODA

Phylum, Arthropoda
Class, Crustacea
Sub-class, Malacostraca
Order, Decapoda
The Crayfish

General Structure. The body and appendages are encased in a strong protective *exoskeleton* which is a product of the underlying epidermis and is jointed to provide for movement. The body is divided into two parts: the anterior *cephalothorax,* which is covered by a continuous shield, the *carapace;* and a posterior *abdomen,* composed of distinct, movable segments. Study the nature of the articulations and the direction of movement.

A shallow *cervical groove* in the carapace marks the line of separation between the head and thorax. The anterior spine-like extension of the head is the *rostrum* which lies between the two movable, *stalked eyes.* What is the advantage of this arrangement? The *mouth* lies on the ventral aspect of the head and is almost concealed by the oral appendages.

The *thoracic division* of the carapace includes on each side, a free flap, the *branchiostegite,* which covers the gills. Some of the gills may be seen if the posterior margin of the branchiostegite is carefully lifted.

Examine the ventral aspect of the cephathorax for evidences of segmentation. Thirteen segments or *metameres* are present, and the same number of appendages. How many segments and appendages are present in the abdomen? The terminal piece of the abdomen, the *telson,* has no appendages. It is usually not considered a true segment.

Drawing I. A lateral view of the animal, omitting the appendages. Label the following:

(1) cephalothorax
(2) carapace
(3) cervical groove
(4) rostrum
(5) branchiostegite
(6) abdominal segments
(7) telson
(8) mouth (indicate location)
(9) stalked eyes

Appendages. Each segment of the crayfish bears a pair of *jointed appendages.* These differ greatly in the various parts of the body, but all are modifications of one common type and serially homologous one with another. The anterior appendages form sense organs; those in the region of the mouth act both as jaws and sense organs; the remainder are primarily organs of locomotion.

The *appendages of the head* include a pair of *antennules,* a pair of *antennae,* a pair of *mandibles,* and two pairs of delicate leaf-like *maxillae.* The mandibles are the horny, toothed jaws, between which lies the mouth. Each mandible bears a short jointed *palpus,* a sense organ.

The *appendages of the thorax* consist of three pairs of accessory jaws, or *maxillipeds,* and five pairs of *walking legs.* The first walking legs are the large pinchers or *chelae.*

The *appendages of the abdomen* are six pairs of *swimmerets.* The two anterior pairs in the male are modified for transmission of sperm. The appendages of the sixth pair in both sexes are much enlarged. They form, with the telson, a *tail fin.* How is the tail fin used?

The *typical appendage* of the crayfish is a biramous structure with a *basal protopod,* and two distal branches; a median *endopod* and a lateral *exopod.* This structure is repeated in the appendages of the third to the sixth abdominal segments in both sexes; it appears also in the three maxillipeds, where the exopod is a sense organ or *palp,* while the endopod is an accessory jaw. In the antenna, the endopod is a long filamentous sense organ; the exopod, a strong scale which protects the eye. Chelae and walking legs have no exopod.

Drawing II. Typical appendages. Label the parts:

(1) antenna, with excretory opening
(2) third maxilliped
(3) third swimmeret

Gill Chamber and Gills. Cut away the left branchiostegite and expose the branchial chamber.

The *gills* are highly vascular external outgrowths from the sides of the thorax and from its appendages. The branchial chamber is situated between the branchiostegite and the true wall of the thorax. At the anterior end of the chamber is a conspicuous groove containing a process of the second maxilla, the *scaphognathite.*

The *circulation of water* through the gill chamber is due to the action of the scaphognathite, which oscillates in such a manner as to pump water out of the anterior part of the gill chamber. Fresh water enters posteriorly and ventrally beneath the free margin of the branchiostegite. Demonstrate the existence of these currents in the living crayfish by using water containing powdered carmine.

There are two rows of gills. The *podobranchiae* are attached to the basal joints of appendages seven to twelve. The *arthrobranchiae* arise from the arthrodial membranes at the bases of the thoracic appendages. At the base of each of the appendages eight to twelve are two arthrobranchiae, an anterior and a posterior one. A single gill is attached to the arthrodial membrane of the seventh appendage. What is the significance of the attachment of the gills to the appendages?

Drawing III. The gill chamber and gills. Show:

(1) podobranchiae
(2) arthrobranchiae of segments eleven and twelve (make clear the attachment of these)
(3) scaphognathite

Digestive Organs. Carefully remove the exoskeleton from the dorsal region of the body. In the head and abdomen, note the attachment of muscles to the inner surface of the skeleton. The soft layer under the skeleton includes the epidermis, which produces the protecting covering. Remove the soft body wall and expose the underlying organs.

The *oesophagus* is a short wide tube running vertically upward from the mouth. It leads into the *stomach,* a wide chamber occupying the great part of the head and extending a short distance into the thorax. The stomach consists of a large anterior or *cardiac* chamber and a smaller posterior or *pyloric*

chamber. The two parts are separated from each other by a constriction. The cardiac chamber is a *stomodaeum* and is provided with a gastric mill consisting of strong chitinous teeth. The oesophagus leads to the stomodaeum.

In the *pyloric* chamber or true stomach, the food is mixed with secretion from the *liver-pancreas*. It then passes through the *intestine,* a narrow, straight tube where digestion is completed and absorption occurs. The waste is ejected through a longitudinal slit, the *anus,* which is on the ventral surface of the telson.

The *liver-pancreas* is a large brown or greenish organ with two lobes, one on each side, adjacent to the stomach. Its secretion, which acts on proteins, carbohydrates, and fats alike, is poured into the pyloric part of the stomach through two ducts, one on each side.

Circulatory Organs. *The pericardial sinus* is a cavity of considerable size in the dorsal portion of the thorax, behind the stomach. In the sinus lies the thick-walled, *muscular heart.* Find arteries which carry blood from the heart to the body. Look for three pairs of valves in the wall of the heart. What is the function of these valves? Read the text-book on the circulation.

Reproductive Organs. The sexes are separate. The single gonad, ovary or testis, is a Y-shaped organ, whose two anterior lobes lie against the sides of the stomach, while the single posterior lobe extends backward under the pericardial sinus. The *ovary* varies in size according to the stage of development of the eggs which it contains. The *oviduct* of each side passes from the median lobe directly downward to its opening on the base of the third walking leg. In the male, the *vas deferens* is a much coiled duct which opens on the base of the last thoracic appendage.

Excretory Organs. *The nephridia,* or green glands, are short coiled tubes which form a pair of light green bodies in the head, anterior to the oesophagus. The duct on each side opens through a small tubercle on the basal joint of the antenna.

The Muscles. The most conspicuous muscles are the flexors

and extensors of the abdomen. The large flexors occupy the greater part of the space within the abdominal segments; the smaller extensors lie under the roof of the abdomen, on each side of the intestine. Do you understand the function of these abdominal muscles?

The tubular appendages contain muscles which produce a variety of movements. Remove the exoskeleton from one side of a pincher and study the attachment and operation of the muscles inside.

Two mandibular muscles arise from the roof of the carapace, one on each side of the stomach; they are inserted on the mandibles by slender tendons. The dorsal attachments of these muscles were cut when the carapace was removed from the head. Determine the function of these muscles.

DRAWING IV. The internal organs in place. Label:

(1) stomach—
cardiac portion
pyloric portion
(2) mandibular muscles
(3) intestine
(4) liver-pancreas
(5) pericardial sinus
(6) heart
(7) ovary or testis
(8) excretory organs
(9) flexors and extensors of the abdomen

The Nervous System. Carefully remove the viscera of the cephalothorax and the muscles of the abdomen. Find the nerve cord in the floor of the abdomen and do not injure it as you proceed with the dissection. In the thorax, the cord passes into a canal, the *ventral blood sinus,* which is roofed over by chitinous plates. These must be removed carefully. The *ladder type nervous system* will now be exposed.

The *brain* is a supraoesophageal ganglionic mass in segments one and two. It supplies nerves to the eyes, the antennules, and the antennae. A pair of long nerve cords, *circumoesophageal connectives,* connects the brain with a ganglionic mass on the ventral side of the oesophagus. This is the *suboesophageal ganglion,* which includes the fused ganglia of segments three to seven. It sends nerves to the mandibles, maxillae, and to the first and second maxillipeds.

Behind the suboesophageal ganglion, the thoracic portion of the nerve chain includes six ganglia which supply the appendages eight to thirteen.

The *abdominal portion* of the nerve chain includes six ganglia joined together by connectives. The large posterior ganglion supplies both the nineteenth segment and the telson.

DRAWING V. The nervous system. Label the following:

(1) brain
(2) circumoesophageal connectives
(3) suboesophageal ganglion
(4) thoracic nerve chain
(5) abdominal nerve chain

The sense organs. Sensory hairs which are organs of touch and chemical sense are distributed over the body. These organs are especially abundant on the anterior appendages.

Statocysts. Study the base of the antennule and note the concave surface directly under the eye. Remove the antennule and find in the concave area a minute opening protected by hairs. The opening leads into a sack lined with sensory hairs, among which lie small grains of sand. This structure is the *statocyst,* or organ of equilibrium.

The *eyes* are compound; each one is composed of numerous pyramidal units, the *ommatidia.* The usually square bases of these pyramids are covered by the transparent cornea, a modification of the exoskeleton. Cut a vertical section through the middle of an eye and note the form of the ommatidia.

DRAWING VI. (a) A part of the cornea
(b) A section showing ommatidia

Phylum, ARTHROPODA
Class, INSECTA
Order, ORTHOPTERA
The Grasshopper

External Anatomy. If the season permits, living specimens should be used along with preserved material in this study. The grasshopper belongs to the Insecta, which have three body regions: *head, thorax* and *abdomen.*

a. The *head* bears a pair of large *compound eyes* (similar to those of the crayfish) and three simple eyes, the *ocelli.* It has also a pair of filamentous sense organs, the *antennae,* and three pairs of mouth appendages. The latter will be described later.

b. The *thorax* is composed of three segments: a *prothorax,*

a *mesothorax,* and a *metathorax,* each of which bears a pair of legs. The prothorax is a separate, movable segment; the mesothorax and metathorax are joined together and each bears a pair of wings.

The *legs* have five parts. Beginning at the proximal end, these are the coxa, trochanter, femur, tibia and tarsus, the last with four movable pieces. In the leaping legs, coxa and trochanter are united. Study the leaping legs as adaptations to their use in the living animal.

Study the anterior and posterior wings. Note especially the folding of the latter. Compare the functions of the two pairs of wings.

c. The *abdomen* is composed of similar movable segments, each of which is divided by membranes into a dorsal *tergum* and a ventral *sternum.* The membranes provide for dilation and contraction of the abdomen during the process of respiration. The first abdominal segment is an incomplete ring. It bears a pair of *auditory organs,* each covered by an oval *tympanic membrane.*

Find the respiratory openings, the *spiracles,* which lie on the sides of the thorax and abdomen. In the abdomen, each of the eight anterior segments has a pair of spiracles, one on each side of the tergum near its ventral margin.

Abdominal appendages are wanting, but the terminal segments bear a four-piece *ovipositor* in the female, and organs for sperm transfer in the male. These are not homologous with the anterior true appendages.

Drawing I. A lateral view with wings folded. Label:

(1) the head, antennae, compound eyes, ocelli
(2) the thorax, its three divisions and spiracles
(3) five parts of the leaping leg
(4) anterior wings
(5) abdomen, with sterna, terga, spiracles, male or female appendages

Drawing II. A dorsal view with the wings spread.

The mouth parts. Remove the labrum, or upper lip, which lies in front of the mouth. It is not a true appendage. Behind the labrum is a pair of chewing *mandibles,* which are followed by a pair of accessory jaws or maxillae. These are divided into

three parts, a toothed lacinia, a spoon-shaped galea, and a palpus. The appendages of the posterior pair are fused together to form the *labium,* or lower lip, which bears a jointed palp on each side.

Drawing III. The mouth parts. Place them in proper order and make drawings large enough to show clearly the structure. Label the following:

(1) labrum
(2) mandibles
(3) maxilla
(4) labium with palpus

Internal Organs. Cut off the wings, then carefully make a longitudinal incision on each side of thorax and abdomen and remove the dorsal wall of these regions.

a. The *tubular heart* will probably be removed with the abdominal wall, to which it is closely attached by fan-shaped bundles of *muscle fibers.*

b. The *wing muscles* occupy a large part of the thorax. Examine a few muscle fibers under high power. Do you find striations?

c. *Tracheae.* Using the muscle preparation, look for small air tubes or *tracheae* which carry air from the spiracles into the body. They may be found among the muscle fibers. Note the spiral thickenings in the wall of the tubes. Larger tracheae and air sacs may be seen with the naked eye, especially in fresh material. If possible, observe the respiratory movements in a living animal.

Drawing IV. The tracheae and muscle fibers as seen under the microscope.

d. The *gonads* lie in the dorsal part of the abdomen, surrounded by fat and tracheae. They differ considerably in the two sexes. When filled with mature eggs the ovaries occupy a large part of the abdomen. The oviduct opens between the plates of the ovipositor.

e. *The alimentary canal.* Remove the wing muscles and turn the gonads backward so as to expose the alimentary canal.

The anterior division is a *stomodaeum* which includes the mouth, oesophagus and a crop, or grinding stomach, which is lined with chitinous teeth. Posteriorly the crop is separated from the *stomach* by a short constriction which is more or less

concealed by a series of blind sacs, the *gastric caeca,* which open into the stomach. A second constriction separates the stomach and intestine; numerous *excretory tubules* open into it. The posterior part of the intestine includes a colon and a rectum. In the female, the last can be seen only after removal of the ovaries.

Drawing V. The internal organs, dorsal view. Label:

(1) crop
(2) stomach
(3) gastric caeca
(4) intestine
(5) excretory tubules
(6) gonads
(7) outline of body

f. *The nervous system.* Remove the alimentary canal and gonads and expose the ventral part of the *ladder type nervous system.* It includes a *suboesophageal ganglion,* three *thoracic ganglia,* and five abdominal ganglia, all connected by double nerve cords. The *circumoesophageal connectives* run forward to the *brain,* or cerebral ganglion, which lies in the head.

Drawing VI. The nervous system. Label the parts named above.

Phylum, Arthropoda
Class, Insecta
Order, Coleoptera
The Beetle

Compare the beetle with the grasshopper in the following respects:

(a) The divisions of the body.

(b) The appendages of the head. Are they similar to those of the grasshopper? Study a living specimen, if possible.

(c) The appendages of the thorax. Note the form and structure of the anterior wings. Find the posterior wings and note how they are folded. What is the function of the anterior wings? Compare the legs with those of the grasshopper.

(d) Count the segments of the abdomen and look for spiracles.

Drawing I. A dorsal view of the beetle. Enlarge about four times and show the wings spread.

Phylum, Arthropoda
Class, Insecta
Order, Lepidoptera
The Butterfly

Compare the butterfly with the grasshopper and beetle in the following respects:

(a) The regions of the body.

(b) The appendages of the head. The form of the *antenna* is characteristic of butterflies. The mouth parts are reduced in number and only the coiled *proboscis* and the *labium* are conspicuously developed, the former being modified maxillae. Separate the two halves which form the proboscis. Observe the use of the proboscis in living forms, if possible. Rudimentary *mandibles* may be found above the base of the proboscis in some butterflies. In the family *Microlepidoptera,* mandibles and maxillae are well developed.

(c) The appendages of the thorax: the legs and wings. Examine the wings with a good hand lens and note their peculiar structure. Scrape the wing with a knife and study the scrapings under high power. Examine the part of the wing from which some of the scales have been removed.

Drawing I. A side view of the butterfly. Show the regions of the body and the appendages of head and thorax.

Drawing II. A portion of a wing showing scales and their attachment.

Insect Larvae

Study the larva of one of the Lepidoptera or Coleoptera and compare it with the mature animal. Head, thorax and abdomen are present. Note the relative size of these regions.

The head. Are compound eyes present? Study the mouth parts. What kind of food does the larva use? Do the larvae of the beetle, butterfly, and moth have similar mouth parts?

The thorax and abdomen. Study the appendages of these regions. The *thoracic legs* are jointed. How many segments in the thorax? The appendages of the abdomen are called *prolegs;* they disappear during metamorphosis. Note the large

spiracles on the sides of the abdomen. Do you find spiracles on the thorax?

Examine *pupae* of some insect. What changes occur within the pupa during the "resting stage"? In what different ways are pupae protected?

DRAWING I. A side view of the larva. Label:

(1) regions of the body
(2) thoracic legs
(3) prolegs
(4) eyes
(5) spiracles

CHORDATA

Phylum, CHORDATA
Subphylum, ENTEROPNEUSTA
Genus, *Dolichoglossus (Balanoglossus)*

Specimens are supplied in glass tubes and are not to be removed from them. Use a hand lens for study of details.

Dolichoglossus is a marine, worm-like animal which burrows in the mud, chiefly in shallow water. The body includes three regions: (a) the anterior club-shaped *proboscis;* (b) the band-like *collar,* whose anterior end fits loosely around the narrow base of the proboscis; and (c) the elongated *trunk,* in which may be recognized three overlapping regions: the anterior pharyngeal, the genital, and the posterior abdominal region. The *mouth* lies at the anterior end of the collar, ventral to the base of the proboscis. The *anus* is at the posterior end of the trunk. The *notochord* and *neural-tube* cannot be seen in these specimens. The former arises within the collar as a tubular outgrowth of the roof of the digestive tract, and extends forward into the proboscis. In its sheath is formed a chitinous, Y-shaped "proboscis skeleton," which gives support to the organs of the proboscis. The *neural tube* lies in the dorsal part of the collar, which contains also a ventral nerve cord. The *gill clefts* include two longitudinal rows of openings in the pharyngeal region of the trunk. The rows are separated by a median dorsal ridge. The gill clefts increase in number posteriorly where they may extend into the region of the gonads. Thus the pharyngeal region may overlap the genital region, which is distinguished by the prominent gonads on each side of the body.

Burrowing Habits. The animal finds safety and food by burrowing in the mud, a certain amount of which is swallowed for the organic matter which it contains. In burrowing, the proboscis and collar are most active; both are well supplied with muscles, and each has a coelomic sac which may be filled

with water through dorsal pores opening to the outside. The turgidity thus produced may be increased by the contraction of the muscles. The burrow is started by the proboscis; after the collar enters the burrow it acts as a holding organ, while the proboscis makes the burrow deeper.

With your specimen before you, review your lecture notes on the anatomy, physiology, and embryology of *Dolichoglossus*.

Drawing I. A lateral view, showing the following parts:

(1) proboscis
(2) collar
(3) mouth
(4) gill clefts
(5) three regions of the trunk

Phylum, Chordata
Subphylum, Tunicata
Order, Ascidiacea
Molgula manhattensis

Obtain a preserved specimen and keep it covered with water or preserving fluid during this study.

Molgula is a fixed animal which is found attached to rocks and piles in shallow sea water. It is the most common, simple, New England tunicate. Individuals occur singly or in clusters, sometimes crowded close together over large areas. In the living condition they contract the body when disturbed, and eject streams of water from two openings or siphons. Because of this habit they are called *sea-squirts*.

External Characters. Note the sack-like form with its felt-like covering, *the tunic*, and its two *siphons*, one incurrent, the other excurrent. Both siphons may be closed in preserved specimens. The area of attachment of the animal is opposite the siphons. Count the tentacle-like lobes at the ends of the siphons. What is their probable function? One of these siphons, the *incurrent*, admits water to the *pharynx*, a large internal sac whose folds converge toward the base of this siphon. In some specimens these folds can be seen through the tunic.

The tunic lies outside of the ectoderm, and in the early stages of its development is purely an epidermal product. Later it is

invaded by mesoderm cells; blood vessels also occur in it. The tunic contains a chemical substance which is apparently identical with the cellulose of plants.

DRAWING I. The external form.

Internal Anatomy. Obtain from the instructor a specimen from which the tunic has been removed. This operation exposes the somewhat transparent *mantle,* through which the pharynx and various organs can be seen. Identify *pharynx, incurrent* and *excurrent* openings and note again the number of lobes at each opening. The incurrent siphon marks the anterior end; the excurrent siphon, the posterior end. The region between the siphons is dorsal. In the region between the pharynx and the excurrent siphon is the dorsal part of the *atrium,* a cavity which also extends ventrally on each side between the mantle and the pharynx.

Using the same specimen, identify the *endostyle,* a whitish band in the mid-ventral line of the pharynx. It begins near the mouth and ends at the posterior end of the pharynx. At its anterior end the endostyle connects with the *peripharyngeal grooves,* which unite dorsally to join the *dorsal lamina.* Recall the functions of these structures.

Study the *left side* and note the following organs, which are attached to the mantle: (a) the *stomach,* enclosed in brownish glands near the posterior end of the pharynx, with which it is connected by a short oesophagus; (b) the *intestine,* which forms a double loop, the posterior end of which, the *anus,* lies in the atrium near the base of the excurrent siphon; (c) the left *hermaphroditic gland,* which lies in the loop of the intestine. It includes a lighter portion, the testis, and a darker portion, the ovary. Oviduct and vas deferens open separately into the atrium.

DRAWING II. The *left side.* Label the following:

(1) siphons
(2) pharynx
(3) stomach
(4) intestine
(5) anus
(6) endostyle
(7) peripharyngeal grooves
(8) dorsal lamina
(9) hermaphroditic gland
(10) cerebral ganglion
(11) subneural gland (see below)

On the *right side,* attached to the mantle, will be seen (a) the right *hermaphroditic gland,* similar to its fellow on the left side; (b) the *heart,* a delicate tube enclosed in a pericardial sac ventral to the hermaphroditic gland; (c) the *excretory organ,* an oval brownish sac which lies ventral to the heart. The heart reverses its beat at regular intervals, the blood flowing from one end through a branchio-cardiac vessel to the pharynx; from the other end, through a cardio-visceral vessel to the mantle organs.

DRAWING III. The *right side.* Label the following:

(1) siphons
(2) hermaphroditic gland
(3) heart
(4) renal organ

The *nervous system* has its center in the *cerebral ganglion,* which lies in the dorsal region between the siphons. It is largely covered by the *subneural gland,* from which a tube, the *hypophysis,* leads to the oral cavity at the anterior end of the dorsal lamina. The opening is elevated to form the *dorsal tubercle. Add the cerebral ganglion to Drawings II and III.*

The interior of the pharynx. Obtain from the instructor a specimen in which the mantle and pharynx have been opened by an incision from the incurrent opening to the oesophagus, close to the line of the endostyle. Examine the interior of the pharynx and identify the parts.

DRAWING IV. The *interior of the pharynx.* Label the following:

(1) endostyle
(2) peripharyngeal grooves
(3) dorsal tubercle
(4) dorsal lamina
(5) pharyngeal folds

The gill clefts. Under low power of the microscope observe the gill clefts, which lie close together in groups, in the thin parts of the pharyngeal wall. Each cleft has a fringe of cilia around the opening. Do you know the function of the cilia?

DRAWING V. The gill clefts, showing cilia.

The atrium. Examine a demonstration specimen showing a transverse section of the body from the base of the excurrent siphon through the middle of the pharynx.

DRAWING VI. A transverse section, showing the relations of the atrium. Label:

(1) layers of body
(2) atrium
(3) pharynx
(4) dorsal lamina
(5) endostyle

Phylum, CHORDATA
Subphylum, CEPHALOCHORDA
Amphioxus lanceolatus

Adult specimens will be furnished in glass tubes and are to be studied without removing them. Young specimens mounted on slides will also be examined.

Amphioxus is a marine animal living in shallow water. It swims freely, but spends much of its time with the posterior half of the body buried in the sand, the anterior end being exposed. The processes of respiration and feeding are similar to those of Molgula.

External Characteristics. Obtain an adult animal in a tube. Count the *myotomes* or muscle segments. They are separated by bands of connective tissue called *myosepta*. Note the *oral hood* at the anterior end, the *atriopore* in segment thirty-six, the *anus* on the left side in segment fifty-two, the low dorsal fin, the conspicuous caudal fin at the posterior end, and the ventral fin, which extends forward to a point just behind the atriopore. From this point two *metapleural folds* continue forward to the oral hood. In mature specimens gonads may be seen through the body wall above the metapleural folds.

DRAWING I. The left side. Label the following:

(1) myotomes
(2) fins
(3) oral hood
(4) cirri (described below)
(5) atriopore
(6) metapleural folds
(7) gonads, if present
(8) anus

DRAWING II. A ventral view. Label:

(1) oral hood
(2) cirri (described below)
(3) metapleural folds
(4) gonads, if present
(5) atriopore
(6) anus

Study of a Young Amphioxus. Obtain a whole mount of a young animal and study under low power. *Do not attempt to use high power.*

The *myotomes, notochord* and *nerve tube* can be easily seen. An *eyespot* lies near the anterior end of the nerve tube.

The *oral hood* has a fringe of tentacle-like *cirri* around the external opening. The hood encloses the *vestibule,* which is bounded posteriorly by a transverse septum, the *velum.* From the margin of the latter, *ciliated lobes* extend forward on the wall of the vestibule. In the living animal they keep water moving from the vestibule into the pharynx.

The *mouth,* which lies in the center of the velum, is surrounded by twelve tentacles; it opens into the *pharynx.* How many gill clefts do you find? Compare your count with that of your neighbors. How many clefts has adult *Amphioxus?* Do you find evidence of the formation of new clefts? Between the pharynx and the external wall of the body is a chamber, the *atrium,* into which the gill clefts open. Find the atriopore. The *hepatic caecum* or liver, the *intestine* and anus are easily seen.

Drawing III. Young Amphioxus. Label:

(1) oral hood
(2) cirri
(3) vestibule
(4) ciliated lobes
(5) mouth
(6) pharynx
(7) atrium
(8) atriopore
(9) liver
(10) intestine
(11) myotomes
(12) notochord
(13) nerve cord
(14) eyespot

A Section of Adult Amphioxus. Obtain a slide with a cross-section through the pharynx region and identify the various structures present. Gonads may be found in these sections. They project into the atrium from the lateral wall of the body.

The vestibule and internal surfaces of the pharynx are provided with cilia which keep water moving into the vestibule, from which it passes in succession through the mouth, pharynx gill clefts, atrium and atriopore. The water currents bring in both food and oxygen, the latter entering the blood which circulates in the wall of the pharynx, while the food is taken up by

a mucous stream which is swept by cilia into the intestine. This food path includes: (a) the *endostyle,* a longitudinal groove in the floor of the pharynx; (b) the *peripharyngeal bands* at the anterior end of the pharynx; and (c) the *epipharyngeal groove,* which lies in the median dorsal line. Food passes along this groove to the intestine.

Drawing IV. A section through the pharynx. Label the following:

(1) epidermis
(2) dorsal fin
(3) myotomes
(4) myosepta
(5) metapleural folds
(6) neural tube
(7) notochord
(8) pharynx
(9) atrium
(10) coelum
(11) gill clefts
(12) endostyle
(13) epipharyngeal groove
(14) gonads (if present)
(15) liver (if present)

Examine also demonstrations showing longitudinal sections, eyespot, etc.

Phylum, Chordata
Subphylum, Vertebrata
Class, Elasmobranchii
Subclass, Selachii
Order, Squali
Squalus acanthias, the Dogfish

External Characters

Note the general form of the body. Head, trunk, and tail may be recognized, but these regions are not sharply separated. How is the shape of the body adapted to aquatic life? Study the distribution of pigment on the surface of the body. Why are dorsal and ventral regions different?

The Appendages. Median and paired fins are present. Unpaired or median fins lie in the median line of the body. They include an *anterior dorsal* fin, a *posterior dorsal* fin, and a *caudal* fin at the posterior end of the body. Each dorsal fin has a spine at its anterior end. The caudal fin is unsymmetrical, the dorsal lobe being larger than the ventral lobe. Such a caudal fin is called *heterocercal.*

The *paired* fins correspond to the paired appendages of land vertebrates. The *pectoral* fins are anterior; the *pelvic* fins posterior. In male dogfishes, the median part of each pelvic fin is modified to form the *clasper,* an organ for the transmission of sperm.

The Openings of the Body. (1) The *mouth* is on the ventral side of the head between tooth-bearing jaws. (2) The *anus,* or cloacal opening, is a longitudinal slit on the ventral surface of the body between the pelvic fins. It is the common outlet for the digestive organs and the urogenital system. (3) Six pairs of *respiratory openings* are present: the spiracles, which lie behind the eyes; the five pairs of gill clefts, which lie between the spiracles and the pectoral fins. Normally the respiratory water enters the mouth and is expelled through the gill clefts, while the spiracles remain closed. Under special conditions the spiracles may be used either as incurrent or excurrent openings. (4) The nostrils lie anterior to the mouth. Each opening is divided by an overlapping fold of skin, so that water enters the anterior half of the opening and escapes from the posterior half.

The Sense Organs. These include eyes, ears, olfactory organs, ampullary and lateral line organs. The last two are adaptations to an aquatic life. The *eyes* have short immovable lids. The *ear* includes only the internal labyrinth, or inner ear, which will be studied later. Each inner ear opens to the exterior through a small canal, the *endolymphatic duct,* which reaches the surface near the median line between the spiracles.

The *ampullary organs* have an uncertain function. The openings of these organs lie in definite patches on the head, the most conspicuous being the *buccal group* anterior to the mouth, and the *supraorbital groups* above and anterior to the eyes. The canals leading to these openings are filled with mucus, which may be forced out by pressing on the skin. Locate these patches. The organs themselves will be seen later.

The *lateral line organs* include a system of subdermal canals and nerves which extend from the rostrum to the tail. The canals open through the skin by minute pores. Under strong oblique light the pores may sometimes be seen without a lens.

The chief canals of the system are the following: (1) The *lateral line* of the trunk and tail begins as an open groove on the side of the tail. Follow the groove forward until it disappears under the skin. Anterior to this point the pores indicate the position of the canal. Trace these forward. At the level of the spiracle, the two lateral lines are connected by (2) a *supratemporal canal.* Continuing forward, each lateral line divides to form (3) a *supraorbital canal,* which passes above the eye; and (4) an *infraorbital canal,* which passes between the eye and the spiracle, then forward below the eye. (5) A *hyomandibular canal,* which arises from the infraorbital canal below the eye, extends backward behind the angle of the mouth.

In aquatic amphibians the lateral line organs are exposed on the surface of the body; canals are wanting.

The ear and lateral line organs are closely related. The latter are stimulated by vibrations of low frequency, the ear by more rapid vibrations.

Scales. The surface of the body is covered with small *placoid scales,* which are products of the skin. Each scale consists of a base which is deeply buried in the dermis, and an oblique spine which projects on the surface. In what direction do the spines project? The body of the scale is *dentine,* which is produced by the dermis. The tip of the spine is *enamel,* which is formed by the epidermis. The structure of these scales are similar to that of the teeth, which are modified scales, formed in the stomodaeal part of the mouth.

Make the following drawings and label the parts named:

DRAWING I. A lateral view of the entire animal.

(1) head
(2) trunk
(3) tail
(4) anterior dorsal fin
(5) posterior dorsal fin
(6) caudal fin
(7) pelvic fin
(8) pectoral fin
(9) eye
(10) spiracle
(11) gill slits
(12) lateral line of trunk and tail
(13) supratemporal canal
(14) supraorbital canal
(15) infraorbital canal
(16) hyomandibular canal
(17) mouth

DRAWING II. Ventral view of entire animal.

(1) rostrum
(2) nasal openings
(3) mouth
(4) teeth
(5) pectoral fins
(6) pelvic fin (with claspers, in the male)
(7) caudal fin
(8) cloacal opening

DRAWING III. Ventral view of the pelvic region of the opposite sex.

DRAWING IV. Dorsal view of head.

(1) rostrum
(2) eyes
(3) endolymphatic ducts
(4) spiracles
(5) gill slits
(6) lateral line
(7) supratemporal canal
(8) supraorbital canal
(9) infraorbital canal

DRAWING V. Placoid scales. Label the parts.

THE SKELETON

The skeleton of the dogfish may be divided into an axial portion composed of the spinal column, ribs and skull; and an appendicular portion, which includes the pectoral and pelvic girdles and the skeleton of the appendages. The skeleton is composed of cartilage only.

The Spinal Column. Cut a cross-section of the tail one inch behind the cloacal opening. Examine the cut surfaces and identify the parts of a vertebra.

A *caudal vertebra* consists of a *centrum* or body, a dorsal *neural arch* and a ventral *haemal arch*. The centrum has the form of a short tube constricted in the middle, the internal cavity being hour-glass-shaped. The cavity is occupied by the pulpy notochord. The neural arch and centrum form the neural canal, for the spinal cord. The haemal arch and centrum form a haemal canal which contains the caudal artery and vein.

Trunk vertebrae have no haemal arch but they have short *transverse processes* which may represent the dorsal parts of such an arch. A short *cartilaginous rib* articulates with each transverse process. Obtain trunk vertebrae from the instructor for comparison with the caudal vertebrae.

DRAWING VI. A cross-section of a caudal vertebra. **Label:**

(1) centrum
(2) notochord
(3) neural arch
(4) neural canal
(5) spinal cord
(6) haemal arch
(7) haemal canal
(8) caudal artery
(9) caudal vein

Remove a few caudal vertebrae from the severed part of the tail and cut a sagittal section. Observe the constricted centra and the notochord which fills the internal spaces. In a series of vertebrae the notochord has the form of a string of beads. The spinal cord lies in the neural canal. Roots of the spinal nerves pass through the small foramina in the sides of the canal.

DRAWING VII. A sagittal section of the caudal vertebrae. Label: centrum, notochord, neural arch, haemal arch, foramina for nerves.

The Skull. The skull of the dogfish is composed entirely of cartilage. It includes two parts: the *cranium* which protects the brain and special sense organs, and the *visceral skeleton* which supports the wall of the oral cavity and pharynx. Obtain a prepared skull from the instructor.

a. The *cranium* is a single piece of hyaline cartilage. Its anterior end, which forms the support of the snout, is called the *rostrum*. Attached to the ventral portion of the base of the rostrum are two *nasal capsules,* which enclose the olfactory organs. Each capsule has two openings: a ventral opening which contains the external naris, and a posterior opening which provides for the entrance of the olfactory nerve. On each side of the cranium posterior to the nasal capsule is a large oval depression, *the orbit,* which is occupied by the eyeball, its muscles, and various nerves and blood vessels. *Foramina* in the wall of the orbit provide for the passage of cranial nerves. Find the large *optic foramen* for the optic nerve. Lateral prominences behind the orbits contain the *auditory capsules,* which are closely united with the cranium. Between the auditory capsules, on the roof of the cranium, is a large median depression through which the endolymphatic ducts open to the outside. At the posterior end of the cranium is the large *foramen magnum,* through which the spinal cord enters the cranial cavity.

b. The *visceral skeleton* includes the mandibular arch, the hyoid arch, and five branchial arches.

The *mandibular arch* supports the jaws. Two *pterygoquadrate cartilages* unite in the median line to form the skeleton of the upper jaw; two *Meckel's cartilages* unite to form a support for the lower jaw. Both upper and lower jaws bear teeth. The pterygoquadrate cartilages are attached to the cranium by ligaments, and each has a strong palatine process which extends into the orbit. Posteriorly the cartilages of the jaws articulate by a hinge joint which allows the mouth to be opened and closed.

The *hyoid arch* includes five segments of cartilage. Two dorsal *hyomandibular cartilages* are joined to the otic region of the skull, one on each side. The single *basihyal* cartilage supports the tongue. Between hyomandibular and basihyal, on each side, lies a *ceratohyal* cartilage. Ligaments connect the pterygoquadrate and Meckel's cartilages with the hyomandibular cartilage, which thus serves as a support for the jaws.

Each *branchial arch* consists typically of nine segments, four on each side, and a median basal cartilage below. Observe the relation of the segments to each other.

Drawing VIII. A lateral view of the skull. Label the following:

(1) the cranium
(2) the rostrum
(3) olfactory capsule
(4) the orbit
(5) auditory capsule
(6) mandibular arch
  a. pterygoquadrate cartilage
  b. Meckel's cartilage
(7) hyoid arch and hyomandibular cartilage
(8) the gill arches

The Appendicular Skeleton. The supporting skeleton of the paired fins includes the girdles which are embedded in the body wall, and the skeleton of the fins. Since the pelvic and pectoral structures are essentially alike, only the latter will be studied. Remove the skin median and dorsal from the base of the left pectoral fin, and from the fin itself. Remove also the small fin muscles which lie above and below the base of the fin.

a. The *pectoral girdle* is a U-shaped cartilage which may be divided into three parts: a median *coracoid portion* between the bases of the two pectoral fins, and a *scapular portion* on each side above the base of the fin.

b. The *skeleton of the pectoral fin* is composed of *basals, cartilaginous rays* and *horny rays*. The basals include three cartilages, a small anterior *propterygium,* a middle *mesopterygium* and a large posterior *metapterygium*. They articulate with the girdle at the *glenoid fossa*. Distal to the basals lie several rows of cartilage rays, and beyond these are the horny rays.

Drawing IX. A ventral view of the pectoral girdle and fin skeleton. Label the following:

(1) coracoid portion
(2) glenoid fossa
(3) propterygium
(4) mesopterygium
(5) metapterygium
(6) cartilage rays
(7) horny rays

The Voluntary or Skeletal Muscles

The muscles of vertebrates may be divided into two functionally different groups: *somatic muscles* and *visceral muscles*. Somatic muscles are voluntary striated muscles which adjust the body to external conditions; they may be divided into two subclasses, axial muscles and appendicular muscles. Visceral muscles produce movements in the digestive, respiratory, circulatory, urogenital systems, etc. They include three subclasses: (a) the voluntary striated muscles of the visceral skeleton, (b) the involuntary striated muscle of the heart, and (c) the smooth muscle of the digestive tract, etc.

Voluntary muscles, including the somatic muscles and the striated visceral muscles, are usually attached to the skeleton and are also called skeletal muscles. Such muscles arise from some relatively fixed part or point called the *origin,* and are inserted on a movable part or point called the *insertion*. Muscles are attached by means of connective tissue, which may take the form of slender cords called *tendons,* or it may give rise to broad sheets called fasciae or aponeuroses, which furnish attachment to one or many muscles. Only the voluntary muscles will be studied.

The Segmented Axial Muscles. These muscles are composed of myotomes similar to those of Amphioxus. Remove a strip of skin from the right side of the tail and expose the

muscles from the mid-dorsal to the mid-ventral line. Observe the *myotomes,* and the *myosepta* of connective tissue which join them together. A horizontal septum, which follows approximately the course of the lateral line, divides the myotomes into dorsal and ventral parts. The dorsal parts form the *epaxial muscles;* the ventral parts, the *hypaxial muscles.*

Drawing X. The segmented axial muscles. Label the following:

(1) myotomes
(2) myosepta
(3) epaxial muscles
(4) hypaxial muscles
(5) the horizontal septum

The External Muscles of the Pharynx Region. Remove the skin from the floor and right side of the mouth and pharynx. Expose the muscles of the visceral arches and the muscles above the gill clefts as far as the mid-dorsal line.

The *segmented epaxial muscles* continue forward from the tail and trunk, and may be seen above the gill clefts next to the middle line. They are covered by a strong sheath of connective tissue, the *dorsal fascia.*

Ventral to these axial muscles lies the *trapezius,* a triangular muscle which arises from the lateral border of the dorsal fascia and is inserted on the scapular portion of the shoulder girdle.

Surrounding the gill clefts is a thin sheet of muscular tissue composed of the *superficial constrictors of the pharynx.* The muscle sheet is divided into *six segments,* which are incompletely separated by the visceral clefts. Each segment includes a *dorsal* and a *ventral constrictor.* The muscles of the first segment are widely separated from each other, the dorsal constrictor lying anterior to the spiracle; the ventral constrictor, in the angle between the two halves of the lower jaw. The muscles of all posterior segments are continuous between the visceral clefts, and the muscles of adjacent segments are joined together above and below the clefts. The muscles of the second segment, which lie between the spiracle and the first gill cleft, form a broad sheet which extends from the mid-ventral line to the dorsal fascia, the dorsal and ventral constrictors being united laterally by a seam of connective tissue. The second ventral constrictor is continuous below with the first. The muscle segments posterior to the second are relatively nar-

row. Observe the vertical bands of muscle fibers which pass between adjacent gill clefts and connect dorsal and ventral muscles of the same segment. What must be the effect of the contraction of these constrictor muscles, as a group, upon the pharynx and upon the gill clefts? Other deeper muscles assist the constrictors but we can not study them. The constrictors are supplied by four cranial nerves: the trigeminus, the facial, the glosso-pharyngeal and the vagus.

Anterior to the constrictor muscles and behind the angle of the mouth is the strong *adductor mandibulae,* which arises from the pterygoquadrate cartilage and is inserted on the posterior end of Meckel's cartilage. What is its function? Which nerve controls it?

Drawing XI. The superficial constrictors of the pharynx and adjacent muscles. Label the following:

(1) epaxial muscles
(2) trapezius
(3) adductor mandibulae
(4) dorsal constrictors
(5) ventral constrictors
(6) the visceral clefts

The Hypobranchial Muscles. The anterior muscles of this group are covered by the first and second ventral constrictors, which meet in the median line behind the lower jaw. Cut through the seam of connective tissue which unites the constrictors and expose the underlying *hypobranchial muscles.* The posterior muscles of the group are the paired *coraco-arcuales,* which arise from the coracoid portion of the pectoral girdle. They are connected anteriorly with a median *coraco-mandibularis,* which is inserted on Meckel's cartilage. Dorsal from the coraco-mandibularis are the paired *coraco-hyoids,* which extend from the coraco-arcuales to the hyoid cartilage. These muscles open the mouth and retract the ventral ends of the visceral arches, thus increasing the vertical diameter of the mouth and pharynx. The hypobranchials are antagonists of the adductor mandibulae and the constrictor muscles described above. Both groups play an important part in respiration and in the swallowing of food.

Drawing XII. The hypobranchial muscles. Label the following:

(1) reflected parts of constrictors 1 and 2
(2) the coracoid portion of the shoulder girdle

(3) Meckel's cartilage
(4) coraco-arcuales
(5) coraco-mandibularis
(6) the coraco-hyoids

Muscles of the Pectoral Fin. Remove the skin above and below the base of the right pectoral fin. The muscles of the fin are relatively weak and produce only limited movements. Examine the dorsal muscle of the fin and determine its approximate function. The ventral muscle, the antagonist of the dorsal muscle, arises from the coracoid part of the pectoral girdle and is inserted in small bundles on the cartilaginous rays of the fin.

Drawing XIII. The ventral muscle of the pectoral fin. Label the parts observed.

The Body Cavity, or Coelom, and its Organs

Open the body cavity by a median ventral incision from the pectoral girdle to the pelvic girdle. Make short transverse incisions through the body wall behind the pectoral girdle and anterior to the pelvic girdle. Then cut through the pelvic girdle on one side of the middle line and prolong the cut backward on the same side of the cloaca.

a. The *coelom,* or body cavity, contains a number of organs which are called collectively the *viscera.* The coelum opens into the cloaca by two abdominal pores, and it is connected with the pericardial cavity by an opening in the transverse septum, which is described below. What is the function of the coelom?

b. The *peritoneum* is the smooth membrane which lines the coelom. The following parts may be distinguished: (1) the *parietal peritoneum,* which lines the internal surface of the body wall; (2) *mesenteries* and *ligaments,* which extend from the body wall to the organs, or from one organ to another; (3) the *visceral peritoneum,* which forms an external covering for the organs themselves. The term ligament is usually applied to a small mesentery, or a part of a mesentery.

c. The *liver* is a large brownish organ, whose undivided anterior end is attached to the posterior surface of the septum transversum, while its two lateral lobes extend far back into the coelom. Between the two lateral lobes is a short median lobe which contains the gall bladder.

At its anterior end the liver is supported by two ligaments: the *coronary ligament,* which fixes the liver to the septum transversum; and the *suspensory ligament,* which extends from the median ventral part of the liver to the adjacent part of the body wall.

The *bile duct* is a thick-walled tube which passes from the gall bladder to the dorsal wall of the duodenum. It lies in the right portion of the *hepato-duodenal ligament,* a small mesentery which connects the liver and duodenum.

d. The *stomach* is a large sack-like organ which lies dorsal to the liver. It is supported by a portion of the dorsal mesentery called the *mesogaster.* The stomach consists of a wide *cardiac portion* into which the oesophagus opens, and a smaller *pyloric portion* which bends toward the right side and diminishes in size. The opening from the stomach into the intestine is the *pylorus,* which is guarded by a ring of smooth muscle.

e. The *intestine* begins with a narrow *duodenum,* which follows the stomach. The liver and pancreas pour their secretions into the duodenum. The wider part of the intestine is the *valvular intestine,* whose surface is marked by a spiral line corresponding to the attachment of an internal fold, the so-called *spiral valve.* Posteriorly the intestine narrows to form a short *rectum* which opens into the cloaca.

The *rectal gland* is a small cylindrical body attached to the posterior part of the intestine by a mesentery, the *mesorectum,* which contains the duct of the gland.

f. The *cloaca* is a short, wide passage which serves as an outlet for the digestive and urogenital organs. In the dorsal wall of the cloaca is a median conical projection. In the male, it is the *urogenital papilla,* which contains the opening of the urogenital organs. In the female, it is the *urinary papilla.* The genital openings of the female are paired slits, one on each side of the urinary papilla. At the anterior end of the cloaca is the opening of the *rectum,* the terminal part of the digestive tract. The *abdominal pores* are two small openings, one on each side of the cloacal aperture; they lead into the coelom.

g. The *spleen,* a part of the lymphatic system, is a dark brown organ attached to the posterior part of the stomach. It is supported by the *gastrosplenic* ligament.

h. The *pancreas* has two lobes: a *ventral lobe* which lies on the ventral surface of the duodenum, and a slender *dorsal lobe* which extends from the duodenum to the dorsal surface of the pyloric part of the stomach. The pancreatic duct enters the duodenum from the posterior part of the ventral lobe.

DRAWING XIV. The abdominal organs. Show the following:

(1) the liver
(2) gall bladder
(3) bile duct
(4) stomach
(5) duodenum
(6) intestine
(7) rectal gland
(8) cloaca
(9) spleen
(10) suspensory ligament of liver
(11) coronary ligament of liver
(12) dorsal mesentery
(13) mesogaster
(14) hepato-duodenal ligament
(15) gastrosplenic ligament
(16) mesorectum
(17) pancreas, dorsal and ventral lobes
(18) lines of attachment of spiral valve

THE PERICARDIAL CAVITY AND HEART

a. The *pericardial cavity* is covered by the coracoid cartilage and by the superficial muscles (coraco-arcuales) which lie anterior to it. The lining of the cavity is the parietal layer of the *pericardium,* whose visceral layer covers the heart itself. Expose the parietal layer by removing the muscles and a part of the coracoid cartilage. Then open the cavity and observe the relations of the two layers of the pericardium. Note also the thin partition, the *septum transversum,* which separates the pericardial cavity from the anterior part of the coelom.

b. *The parts of the heart.* The heart of the dogfish has four parts: a *muscular ventricle;* the *conus arteriosus,* a thick-walled tube which runs from the ventricle to the anterior wall of the pericardial cavity; the *auricle,* an irregular sac which lies dorsal and lateral from the ventricle; a triangular *sinus venosus,* which opens at the apex into the auricle, and is attached by its base to the septum transversum. The posterior angles of the sinus are connected with the ducts of Cuvier, which will be described below. The heart contains only venous blood, which enters the sinus venosus, and passes through auricle, ventricle and conus arteriosus in the order mentioned. From the conus the blood passes forward into the ventral aorta.

DRAWING XV. The pericardial cavity and heart, ventral view. Show the following parts, using dotted lines to indicate the extent of parts which are not in full view:

(1) pericardium, parietal and visceral layers
(2) septum transversum
(3) pericardial cavity
(4) sinus venosus
(5) auricle
(6) ventricle
(7) conus arteriosus
(8) the two ducts of Cuvier

DRAWING XVI. A dorsal view of the heart. Sever the conus arteriosus and the sinus venosus where they are attached to the wall of the pericardial cavity, and remove the heart from the body. Label the different chambers.

c. *Internal structure of ventricle and conus.* Using the heart studied above, make an incision along one side of the ventricle, and continue the incision along the same side of the conus arteriosus. Open the ventricle and note the thick, spongy wall and small central cavity. In the dorsal part of the wall is the *auriculo-ventricular opening*, guarded by two pocket-like folds which open toward the ventricle.

Open the conus under water and find the *semilunar valves.* They are arranged in three circles, three valves in each circle. Two circles lie close together in the posterior part of the conus; the third circle is at the anterior end. What is the function of these valves?

DRAWING XVII. Internal structure of ventricle and conus. Show the following parts:

(1) the ventricle
(2) the structure of the wall
(3) auriculo-ventricular valves
(4) conus arteriosus
(5) semilunar valves

d. *The internal structure of the auricle.* Open the auricle by a lateral incision. It is a thin-walled pouch with a large cavity. Compare the walls of the auricle and ventricle and explain the differences.

The auricle receives blood from the sinus venosus through the *sinu-auricular opening* which is guarded by valves. The auricle is connected with the ventricle by the *auriculo-ventricular opening* mentioned above.

DRAWING XVIII. The open auricle. Show clearly the following:

(1) the cavity of the auricle
(2) the sinu-auricular opening and valves
(3) the auriculo-ventricular opening

The Venous System

The venous system of the dogfish includes the systematic veins, the hepatic portal system and the renal portal system. The portal systems will be studied first.

The Hepatic Portal System. A *portal system* of veins is one that begins and ends in capillaries. The hepatic portal system collects blood from the stomach, intestine, pancreas and spleen and distributes it to the substance of the liver. What is the function of such a system?

The *hepatic portal vein* is a short trunk which lies in the hepato-duodenal ligament close to the bile duct. Anteriorly it divides into two branches, one for each large lobe of the liver. The trunk of the vein is formed by the union of three large tributaries: the anterior and posterior intestinal veins and the gastric vein.

The *anterior intestinal vein* lies on the right ventral surface of the intestine, from which it receives small tributaries. At the anterior end of the intestine the vein enters the ventral lobe of the pancreas and receives a small tributary from the spleen, the *anterior splenic vein.* From the pancreas the anterior intestinal vein passes dorsal to the duodenum and enters the hepato-duodenal ligament.

The *posterior intestinal* vein begins in the rectal region and passes forward on the left dorsal surface of the intestine, from which it receives numerous small tributaries. Near the middle of the intestine the posterior intestinal vein enters the mesentery between the intestine and stomach, where it receives the *posterior splenic vein* and is enveloped by the dorsal lobe of the pancreas. Anteriorly the vein passes dorsal to the pyloric portion of the stomach and enters the hepato-duodenal ligament to meet the other tributaries of the hepatic portal vein: the anterior intestinal vein and the gastric vein.

The *gastric vein* is a large vessel which drains the cardiac region of the stomach. It has two tributaries: the *dorsal gastric vein* and the *ventral gastric vein.*

Arrange the organs so that the course of the vessels can be seen and drawn.

DRAWING XIX. The hepatic portal system. Label the following:

(1) hepatic portal vein
(2) anterior intestinal vein
(3) anterior splenic vein
(4) posterior intestinal vein
(5) posterior splenic vein
(6) gastric vein with its dorsal and ventral tributaries
(7) the digestive organs (label each part)

The Renal Portal System. Cut off the tail by a cross-section behind the cloaca. On the anterior cut surface find the caudal artery and caudal vein in the haemal canal of the vertebra. Which is the artery? Follow the vein forward, if necessary, and observe that the vessel forks directly behind the cloaca. The two veins thus formed are the *renal portal veins,* which continue forward, one on each side, to the *mesonephroi* (plural of mesonephros).

The *renal portal system* includes three chief vessels, the caudal vein and two renal portal veins. The caudal vein receives blood from the tail; the renal portal veins distribute this blood to the mesonephroi, from which the blood enters the postcardinal veins. Recall the structure of a mesonephros.

The Systemic Veins. The systemic veins of the dogfish return the blood to the sinus venosus. The most important of these are the hepatic veins and the two ducts of Cuvier.

The Cuvierian ducts. These are short veins which enter the lateral angles of the sinus venosus. Their chief tributaries, on each side, are a precardinal vein, a postcardinal vein and a lateral abdominal vein. Certain parts of these veins which are greatly enlarged are called sinuses.

The postcardinal veins. From the kidneys the blood is carried by small mesonephric veins into the two postcardinal veins, which lie one on each side of the middle line. As they pass forward the veins receive blood from the body wall and increase in size, the enlarged vessels being called the *postcardinal sinuses.* Near the anterior ends of the mesonephroi the two sinuses communicate with each other across the median line, then diverge laterally around the esophagus to reach the ducts of Cuvier.

The *lateral abdominal* vein is a conspicuous vessel which lies under the peritoneum of the lateral body wall, in the region of

the lateral line. At the posterior margin of the shoulder girdle the vein bends dorsally to reach the lateral end of the duct of Cuvier. Near its entrance into the duct the vein receives the *subclavian vein* from the pectoral fin. Posteriorly the lateral abdominal vein receives also an iliac vein, which collects the blood from the pelvic fin.

The *precardinal sinuses,* which return the blood from the head to the heart, lie above the dorsal ends of the cartilaginous visceral arches and are covered by a thick layer of myotomic muscles. Make a longitudinal incision midway between the gill clefts and the median dorsal line. The sinus is an enlarged vein, which may be traced forward to the orbit, and backward to the duct of Cuvier. In its floor may be seen branches of the vagus nerve. At its anterior end, the sinus opens into the *orbital sinus,* which lies between the eyeball and the wall of the orbit.

The hepatic veins. Examine the open sinus venosus and find in its posterior wall the openings of the two hepatic veins. A probe pushed into these veins passes through the septum transversum and enters the liver. Make an incision in the liver and open one of these enlarged veins.

Note again the ducts of Cuvier, which are connected with the lateral angles of the sinus venosus, and find the openings of the precardinal sinuses and subclavian veins.

Drawing XX. The renal portal and systemic veins. Show the mesonephros, but omit the other viscera. Use arrows to indicate the direction of the circulation and label the following:

(1) caudal vein
(2) renal portal vein
(3) mesonephric veins
(4) postcardinal veins
(5) lateral abdominal vein
(6) iliac vein
(7) subclavian vein
(8) parietal veins
(9) precardinal sinus
(10) duct of Cuvier
(11) hepatic veins
(12) sinus venosus

The Ventral Aorta and Afferent Branchial Arteries

The *ventral aorta,* a continuation of the conus arteriosus, is deeply placed in the muscles of the floor of the mouth and pharynx. Carefully remove the skin and muscles anterior to

the pericardial cavity and find the ventral aorta in the median line.

Three afferent branchial arteries arise from the ventral aorta on each side, the origin of the posterior pair being close to the pericardial chamber. Follow these three arteries laterally on the left side. The anterior artery divides into two vessels, one of which supplies the first demibranch (see below); the other enters the first gill septum. The second afferent branchial artery enters the second gill septum. The posterior afferent branchial artery divides into two vessels, one of which runs to the third gill septum, the other to the fourth gill septum.

Observe the relation of these arteries to the septa, and to the gills. Examine injected demonstration specimens for details not clearly shown in your own.

Drawing XXI. The ventral aorta and afferent branchials. Show the relative size of the vessels and indicate by arrows the direction of the circulation. Label the following:

(1) conus arteriosus
(2) ventral aorta
(3) afferent branchial arteries
(4) gill clefts

Mouth, Pharynx, and Gills

With scissors cut through the lower jaw at the angle of the mouth on the left side, and carry the incision backward across the ventral ends of the gill clefts to the pectoral girdle. Cut away the coracoid cartilage and make a short transverse incision anterior to the septum transversum, so that the floor of the mouth and pharynx may be turned over to the right side. The interior of the mouth and pharynx may now be seen. These form a continuous cavity which becomes narrower posteriorly and opens into the oesophagus.

The floor and lateral walls of the mouth and pharynx are supported by the cartilaginous *visceral skeleton,* which forms a framework around six pairs of gill clefts. Identify the two *pterygoquadrate cartilages* of the upper jaw; two *Meckel's cartilages* in the lower jaw; the *hyoid cartilages* which support the tongue; and the cartilages of the five branchial arches.

The Branchial Clefts. Between the dorsal ends of the *hyoid* and *mandibular arches* on each side, lies the round

spiracle, or first visceral cleft. The other visceral clefts are the true *gill clefts.* Probe the spiracles and clefts and determine their relation to the arches.

Each gill cleft includes an *external opening* which is directed backward and is protected by a valve-like membrane; an *internal opening,* guarded by conical gill rakers which prevent solid particles of food from entering the cleft, and a *gill pouch,* a wide cavity between the two openings.

The Branchial Septa and Gills. The partitions which separate the gill clefts are called *branchial septa,* or gill septa. Each septum is supported by its own cartilaginous arch. Study the cross-sections of branchial septa one to four and observe the following parts: (1) the cartilaginous *branchial arch;* (2) the fleshy portion of the septum, which is supported by smaller cartilages; (3) gill filaments on each side of the septum.

Observe the arrangement of the gill filaments on the branchial septum. A single series of such filaments is called a *demibranch,* and two demibranchs on the same gill septum constitute a *gill.* Note the position and number of demibranchs. How many complete gills are present?

Drawing XXII. The mouth, pharynx, and respiratory organs. Show all parts in proper proportion. On the left side indicate clearly the internal openings of the gill clefts and the cut ends of the branchial septa. The following should be shown:

(1) the roof of the mouth
(2) the floor of the mouth
(3) the teeth
(4) the tongue
(5) the pharynx
(6) the oesophagus
(7) the spiracle
(8) the branchial septa
(9) the gill clefts
internal openings
gill pouches
external openings
(10) gill rakers
(11) sections of branchial septa
(12) the gill filaments
(13) sections of visceral skeleton

Drawing XXIII. Remove a portion of a branchial septum from the left side and draw the gill-bearing surface. Label the following:

(1) the demibranch
(2) the gill filaments
(3) gill rakers

Drawing XXIV. Enlarged cross-section of a gill septum. Show and label:

(1) gill rakers
(2) branchial cartilage
(3) gill filaments of anterior and posterior demibranchs
(4) branchial septum
(5) afferent branchial artery
(6) efferent branchial arteries (These may be added later)

The Teeth. Study the teeth. Note the number of rows, their position on the jaw and different stages of development. Where are new teeth formed? Cut a cross-section of the lower jaw and find the dental groove from which the young teeth emerge.

Drawing XXV. The teeth. Label the old and young teeth, the dental groove and Meckel's cartilage.

Efferent Branchial Arteries and the Dorsal Aorta

The Efferent Branchial Arteries. These vessels receive aërated blood from the gills and carry it to the dorsal aorta.

Remove the mucous membrane from the roof of the mouth and pharynx and from the dorsal ends of the gill arches. Be careful not to injure the blood vessels, which lie under the mucous membrane. Four pairs of large vessels, the efferent branchial arteries, should now be visible.

Follow the arteries to the dorsal ends of the gill clefts and observe that each one is formed at the dorsal angle of the cleft by two vessels, a small artery from the anterior demibranch, and a large artery from the posterior demibranch of the cleft. Examine a demonstration specimen, if necessary, and follow these two arteries to the ventral ends of the clefts where they unite. The fifth gill cleft has no posterior demibranch and its anterior demibranch is drained by a tributary of the fourth efferent branchial artery.

How does the blood pass from the afferent branchial arteries into the efferent branchials?

The Common Carotid Artery. This vessel arises from the arterial loop at the dorsal end of the second visceral cleft, and passes forward to the level of the spiracle, where it divides into the *external* and *internal carotid arteries*. The latter bends toward the median line, where it joins its fellow from the opposite side of the head. The median vessel thus formed enters the cranium, where its branches carry blood to the brain. The

external carotid runs through the cranium to the side of the head.

The common carotid on each side is connected with the first efferent branchial by a vessel which is called the *paired dorsal aorta.*

The Dorsal Aorta. The efferent branchial arteries unite in the mid-dorsal line to form the dorsal aorta, which runs caudalward close to the ventral surface of the spinal column; in the tail, where it becomes the caudal artery, it is enclosed in the haemal arches of the vertebrae. The dorsal aorta distributes blood to the body wall and appendages, to the digestive organs, and to the urogenital system.

A *subclavian* artery arises from the dorsal aorta on each side between the dorsal ends of the third and fourth efferent branchials. Follow the subclavian laterally, dorsal to the postcardinal sinus, and observe its entrance into the pectoral fin. Between the sinus and the fin, the subclavian gives rise to two arteries which supply the abdominal wall: a *lateral abdominal artery,* which passes posteriorly near the lateral line; a *ventral abdominal artery,* which supplies the ventral part of the lateral body wall.

The *coeliac artery* is a large median vessel which arises from the dorsal aorta in the anterior end of the peritoneal cavity. It enters the hepato-duodenal ligament and divides into three branches: (1) the *gastric artery,* which passes to the stomach and divides to form the dorsal and ventral gastric arteries; (2) the *hepatic artery,* which runs forward near the bile duct and enters the liver; (3) the *anterior intestinal artery,* which passes dorsal to the pylorus, gives off small branches to the stomach, duodenum and the ventral lobe of the pancreas, and sends a large branch to the right side of the intestine and the spiral valve.

Posterior to the origin of the coeliac artery, the following vessels arise from the dorsal aorta: (1) the *gastro-splenic artery,* which gives branches to the spleen and adjacent parts of the stomach; (2) the *anterior mesenteric artery,* which supplies the left side of the intestine and spiral valve; (3) the *posterior mesenteric artery,* which supplies the rectum and rectal

gland; (4) paired *iliac arteries,* which carry blood to the pelvic fins.

DRAWING XXVI. The efferent branchials, the dorsal aorta, and its branches. Use arrows to indicate the direction of the blood flow. Label the following:

(1) efferent branchial arteries I to IV
(2) common carotid
(3) internal carotid
(4) external carotid
(5) dorsal aorta
(6) subclavian artery
(7) coeliac artery
(8) gastric artery—dorsal and ventral branches
(9) hepatic artery
(10) anterior intestinal
(11) gastro-splenic
(12) anterior mesenteric
(13) posterior mesenteric
(14) iliac artery
(15) caudal artery

SPIRAL VALVE

The study of the spiral valve has been deferred because it is desirable that the digestive tract should remain undisturbed until the study of the blood vessels is completed.

Remove a portion of the ventral wall of the intestine, beginning with the duodenum. The spiral valve is a membranous fold, attached along one edge to the inner surface of the intestine around which it runs spirally. Study the form of the valve and its attachment to the wall of the intestine. What are the functions of the valve?

DRAWING XXVII. The spiral valve. Use arrows to show the path of food.

THE MALE UROGENITAL SYSTEM

The *excretory and reproductive organs* are closely associated and will be studied together. The immature specimens used in the laboratory may be compared with mature males and females, which will be available for demonstration.

a. The *excretory organs* include the paired *mesonephroi,* or kidneys, and the mesonephric ducts, or *Wolffian ducts.* The mesonephroi are long narrow bodies which lie external to the peritoneum, one on each side of the mid-dorsal line.

b. The *testes* are paired bodies located in the anterior part of the coelom, dorsal from the liver. Each testis is attached to

the dorsal body wall by a short mesentery, the *mesorchium*. Delicate tubes, the *vasa efferentia*, connect the testis with the anterior mesonephric tubules, which conduct the sperm to the mesonephric duct. Thus the mesonephric duct, or Wolffian duct, functions both as sperm duct and as excretory duct.

c. The Wolffian ducts of the young male dogfish are almost straight tubes which lie, one on each side, near the median margin of the mesonephros. In the adult animal the anterior part of the duct becomes very much convoluted, while the posterior portion enlarges to form an elongated sac, the *seminal vesicle*. Posterior to the seminal vesicles the two Wolffian ducts unite and the single tube continues back to the cloaca, where it opens at the end of the urogenital papilla.

Drawing XXVIII. The male urogenital system. Show the following:

(1) testes
(2) mesorchium
(3) vasa efferentia
(4) mesonephroi
(5) Wolffian ducts
(6) seminal vesicles
(7) cloaca
  (a) urogenital papilla
  (b) rectal opening
  (c) abdominal pores

The Female Urogenital System

a. The *mesonephroi* of the female are similar to those of the male, but the Wolffian ducts carry only urine. They are deeply embedded in the substance of the mesonephroi near the median line. Posteriorly the two Wolffian ducts unite to form a median tube which opens into the cloaca at the end of the *urinary papilla*.

b. The *ovaries* are located in the anterior part of the peritoneal cavity, dorsal to the liver. Each ovary is attached to the dorsal body wall by a mesentery, the *mesovarium*. In mature animals the large ova form conspicuous elevations on the surface of the ovaries.

c. The *oviduct* of the young female is a slender tube which lies on the ventral surface of the mesonephros. Anteriorly the two oviducts bend around the liver and enter the suspensory ligament, where they unite and form a single opening, the *ostium*. Through this opening the eggs enter the oviduct from the coelom. Trace the oviducts caudalward to the cloaca and find their openings, one on each side of the urinary papilla.

In the adult dogfish the middle parts of the oviducts become enlarged and are suspended from the dorsal wall by conspicuous mesenteries. In this region each oviduct forms an anterior *shell gland* and a posterior enlargement called the *uterus*. The latter may contain eggs and young.

The eggs are set free in the coelom by the rupture of the ovary, and pass through the ostium into the oviduct, where they are fertilized. The eggs remain in the uterus during development and the young are born as small active dogfish. The embryo is nourished by the large yolk, but the wall of the uterus may contribute a certain amount of nutritive material.

DRAWING XXIX. The female urogenital system. Label the parts seen:

(1) ovaries
(2) mesovarium
(3) oviducts
(4) ostium
(5) shell glands
(6) uteri
(7) mesonephroi
(8) Wolffian ducts
(9) cloaca (see p. 75)
  (a) rectal opening
  (b) urinary papilla
  (c) openings of oviducts
  (d) abdominal pores

THE EYE

Lateral View. The eyes have immovable upper and lower lids, which are lined by the *conjunctiva,* a smooth layer which also covers the exposed surface of the eyeball. The transparent portion of the wall of the eyeball is the *cornea,* which is continuous with the opaque *sclera.* Behind the cornea, inside of the eyeball, is the dark colored *iris,* which is perforated by an opening, the *pupil.*

DRAWING XXX. An external view of the eye. Label sclera, cornea, iris, pupil, eyelids.

Dorsal View of the Eyeball. The eyeball rests in a concavity of the skull called the orbit and is held in place by six striated muscles and by the optic pedicle. The optic nerve connects the eyeball with the brain.

The *muscles of the eyeball* may be divided into two groups. The anterior group includes two muscles, the *superior oblique* and the *inferior oblique,* which have their origin in the anterior part of the orbit. Four *recti muscles* form the second group. They arise in the posterior part of the orbit and are arranged in

pairs. One pair includes the *superior rectus* and the *inferior rectus;* the other includes the *internal rectus* and the *external rectus*. Study the relations of these muscles and determine their functions.

The *optic pedicle* is a cartilaginous stalk which extends from the wall of the orbit to the eyeball; it is surrounded by the recti muscles.

The *optic nerve* arises from the median surface of the eyeball and enters the cranium through the optic foramen.

Drawing XXXI. Show a diagrammatic dorsal view of the muscles and eyeball in the orbit. Label the sclera, cornea, optic nerve, optic pedicle and the muscles of the eyeball.

The Structure of the Eyeball. Cut through the attachments of the eyeball and remove it from the orbit. Observe again the parts shown in the preceding drawing. Remove a portion of the anterior wall of the eyeball and expose the internal cavity.

The *wall of the eyeball* consists of three layers, but only the outer one is a complete covering. This outer investment is a strong fibrous layer which includes the *sclera* and the *cornea.* The sclera covers the deeper, more opaque part of the eyeball; the cornea is the outer transparent part of the wall, through which light enters the eyeball.

The *choroid,* or middle layer, is a dark, pigmented membrane which adheres closely to the sclera, but is separated from the cornea to form the iris. The "color" of the eyes of vertebrates is determined by the presence or absence of pigment in the iris.

The retina. The sclera, cornea and choroid furnish protection and support to the retina, a nervous layer which lies internal to the choroid. The retina includes different strata of nerve cells, the outer one of which is composed of *rod and cone cells,* receptors of the stimulus; while an inner stratum of *ganglion cells* gives rise to the axons which form the optic nerve. In the laboratory specimens the retina is often separated from the choroid except in the region of the optic nerve. What is the blind spot?

The *lens* is a solid spherical body which lies behind the iris.

It is held in place by a suspensory ligament and can be moved in and out to accommodate the eye to near and far objects.

The lens and iris divide the internal cavity of the eyeball into two parts; an *external chamber* which contains a lymph-like fluid, the aqueous humor; and an *internal chamber* filled by a jelly-like substance, the vitreous humor. The pupil regulates the amount of light which enters the internal chamber.

Drawing XXXII. A section through the axis of the eyeball and optic nerve. Label the following:

(1) sclera
(2) cornea
(3) choroid
(4) iris
(5) retina
(6) optic nerve
(7) blind spot
(8) pupil
(9) lens
(10) external chamber
(11) internal chamber

The Ear

The dogfish has only an *internal ear.* It consists of a *membranous labyrinth,* which is inclosed in a *cartilaginous labyrinth* of the same general shape. The whole is located within the *ear capsule,* posterior to the orbit and median to the spiracle. Each membranous labyrinth opens on the surface by means of a slender duct, the *endolymphatic duct.* Find the two openings near the middle line of the head, between the spiracles.

Remove the skin and muscles covering the dorsal surface of the ear capsule on the left side. A longitudinal elevation of the chondrocranium will be noted. Very carefully shave off the cartilage of the elevation. Owing to the transparency of the cartilage, the internal parts may be seen before they are actually exposed, and the dissection, though requiring care, is not difficult. Continue to remove the cartilage without injuring any of the parts that are brought into view.

The *cartilaginous labyrinth* of the dogfish consists of a *vestibule* and *three semicircular canals.* The vestibule is a laterally compressed cavity lying in the ventral and median part of the auditory capsule. The canals include an *anterior vertical,* a *posterior vertical* and a *horizontal* canal, all of which open into the vestibule.

The *membranous labyrinth* includes the *utriculus* and *sacculus* which lie within the vestibule, and *three semicircular canals*

which are contained in the corresponding cartilaginous canals. The membranous semicircular canals are delicate tubes, both ends of which open into the utriculus. Each canal is dilated at one end to form the *ampulla* which contains patches of sensory cells. The canals are at right angles to each other, two canals being located in vertical planes, the third in a horizontal plane. The ampullae of the *anterior vertical* and *horizontal* canals are in contact with each other. The ampulla of the posterior vertical canal is situated ventral to the horizontal canal.

The entire membranous labyrinth is filled with lymph-like fluid, the *endolymph.* The space between the membranous labyrinth and the wall of the cartilaginous labyrinth is filled with a similar fluid, *perilymph.*

The utriculus, sacculus, and ampullae contain patches of sensory cells, to which run branches of the auditory nerve. The patches may be seen with a lens. How do vibrations reach the sensory cells of the ear? What are the functions of the different parts of the ear?

Drawing XXXIII. The internal ear. Label the parts you find:

(1) vestibule, with utriculus and sacculus
(2) anterior vertical semicircular canal
(3) posterior vertical semicircular canal
(4) horizontal canal
(5) ampullae
(6) endolymphatic duct

The Olfactory Organ

The olfactory organs are enclosed in the nasal capsules of the skull. Cut away the margins of the external opening and examine the interior of the olfactory chamber. It is lined by *olfactory epithelium,* which is thrown into numerous parallel folds. The *olfactory nerve* is formed by the axons of nerve cells which lie in the olfactory epithelium.

The Brain

Remove the skin and thick muscle from the top of the head and from the dorsal portion of the trunk just behind it. Examine the ampullary organs and the lateral line organs, as you separate the skin from the head. Carefully remove the cartilage which forms the roof of the skull and expose the brain

and cranial nerves. The latter appear as white strands passing through the cartilage. Do not injure them.

The cranial cavity is only partly filled by the brain itself. In the living animal, a lymph-like fluid occupies the space between the brain and the cranium. Identify the divisions of the brain.

The *olfactory* lobes lie at the anterior end of the brain. They are connected by the olfactory tracts with the olfactory bulbs, which lie in contact with the wall of the olfactory organ.

The *cerebral* hemispheres are separated from the olfactory lobes by a slight constriction; the two cerebral hemispheres are closely united. The cerebrum is largely an organ of smell in all fishes.

The *thalamencephalon* is a short constricted section, which lies behind the cerebrum. Projecting dorsally from the thalamencephalon is the stalked *pineal body,* which may have been removed with the brain case. A projection from the floor of the thalamencephalon is the infundibulum, whose distal portion unites with an ectodermal outgrowth of the roof of the mouth, to form the *hypophysis,* or *pituitary body.* Both cerebrum and thalamencephalon belong to the *forebrain.*

The *optic lobes,* which follow the thalamencephalon, belong to the midbrain.

The *cerebellum* is an oval body, which overlaps both the optic lobes and the *medulla oblongata.* Faint transverse and longitudinal grooves slightly divide the cerebellum into four quadrants. This part of the brain is a center for the co-ordination of motor impulses.

The *medulla oblongata* which lies below and behind the cerebellum, is continuous with the spinal cord. Anteriorly, the medulla includes a pair of lateral wing-like processes, the *restiform bodies,* which are united with each other beneath the overhanging cerebellum.

Drawing XXXIV. A dorsal view of the brain. Label the following:

(1) olfactory lobes
(2) cerebrum
(3) thalamencephalon
(4) pineal body (if seen)
(5) optic lobes
(6) cerebellum
(7) medulla oblongata
(8) restiform bodies

NOTE: The brain and cranial nerves will be shown in one drawing. Place the brain on one side of the center of the paper so that sufficient room will be left for the nerves.

Remove a portion of the roof of the cerebrum on each side and expose the internal cavities, or *lateral ventricles*. Each of these opens through a *foramen of Monro* into a median *third ventricle*, which lies in the thalamencephalon. From the latter, a narrow passage, the *aqueduct of Sylvius*, passes through the midbrain, behind which it opens into the wide *fourth ventricle* in the medulla. From the aqueduct, small *optic ventricles* extend into the optic lobes.

DRAWING XXXV. The ventricles of the brain.

THE CRANIAL NERVES

The dogfish has ten pairs of cranial nerves.

1. The *olfactory nerve* is composed of the axons of olfactory neurons which lie in the olfactory epithelium of the nasal cavity. These axons pass in small bundles into the *olfactory bulb*, which is connected by the *olfactory tracts* with the *olfactory lobe* of the brain. The olfactory nerve is a purely sensory nerve.

2. The *optic nerve* is formed by the axons of ganglion cells which lie in the retina. Its fibers terminate in the thalamencephalon and in the optic lobes.

3. The *oculomotor* nerve arises from the ventral surface of the midbrain and enters the orbit near the origin of the superior rectus muscle. This is a motor nerve which supplies four muscles of the eyeball: the inferior oblique, inferior rectus, superior rectus and internal rectus.

4. The *trochlear nerve* is a small nerve which arises from the roof of the midbrain under the anterior lobe of the cerebellum. Follow the nerve through the cranial wall to the superior oblique muscle which the nerve controls.

5. The *trigeminus* is a large nerve which arises from the antero-lateral part of the medulla in close relation to the seventh and eighth nerves. It enters the orbit and divides into four branches: (1) The *superficial ophthalmic* nerve passes forward through the dorsal part of the orbit and supplies the skin on the dorsal surface of the snout. This nerve is accom-

panied by fibers of the superficial branch of the seventh cranial nerve. (2) The *deep ophthalmic* branch passes forward through the orbit ventral to the superficial branch of the fifth, with which it unites in the anterior part of the orbit. (3) The *maxillary branch* of the fifth nerve runs diagonally across the floor of the orbit to supply the upper jaw, and the skin on the ventral surface of the snout. In its path through the orbit the maxillary branch is accompanied by the buccal branch of the seventh nerve. (4) The *mandibular branch* of the fifth nerve passes outward across the posterior wall of the orbit to the lower jaw. Its motor fibers control the masticatory muscles; its sensory fibers supply the skin in the region of the lower jaw.

6. The *abducens nerve* is a slender nerve which arises from the ventral surface of the medulla posterior to the trigeminus. It passes into the orbit with the fifth nerve and supplies the external rectus muscle.

7. The *facial nerve* is the nerve of the hyoid arch. It arises from the antero-lateral surface of the medulla in close relation with the fifth nerve. The seventh nerve has four branches. (1) The *superficial ophthalmic branch* accompanies the superficial ophthalmic branch of the trigeminus, and supplies the supraorbital canal and the adjacent ampullary organs. (2) The *buccal nerve,* already mentioned above, is distributed to the lateral line organs below and anterior to the eye. (3) The large *hyomandibular* trunk is a mixed nerve which may be found directly behind the spiracle. It contains motor fibers for muscles of the hyoid arch, sensory fibers for the mucous membrane of the mandible, and lateral line fibers for the mandibular and hyomandibular canals and for the adjacent ampullary organs. Follow the hyomandibular nerve from the region of the spiracle toward the brain. Near the union of the nerve with the trunk of the facial, will be seen the geniculate ganglion, from which arises (4) the *palatine* branch of the facial nerve. This is a slender nerve which supplies the epithelium and taste buds of the roof of the mouth. It is purely sensory.

8. The *auditory nerve* arises from the medulla behind the seventh nerve. Its branches supply the sensory patches of the utriculus and sacculus and the ampullae of the semicircular canals.

9. The *glossopharyngeal nerve* is the nerve of the third visceral arch. It emerges from the medulla posterior to the eighth nerve and passes through the floor of the auditory capsule, where it forms the petrosal ganglion. Outside of the skull the nerve divides into three branches: (1) a small sensory branch for the anterior wall of the second visceral cleft, (2) a sensory branch which enters the mouth, and (3) a mixed branch which passes behind the second visceral cleft. Its sensory fibers run to the epithelium of the posterior wall of the cleft; its motor fibers supply the muscles of the third visceral arch.

10. The *vagus* nerve supplies visceral arches *four to seven.* It arises from the posterior part of the medulla and passes laterally through the posterior part of the ear capsule. On the median side of the anterior cardinal sinus the nerve divides into two larger branches: (1) a median or *lateral line* branch which runs posteriorly to supply the lateral line of the trunk, and (2) a *visceral* branch which supplies the four posterior visceral arches, the stomach and intestine. The branchial nerves pass under the floor of the anterior cardinal sinus to reach their gill arches. They give rise to sensory nerves for the walls of the gill clefts and pharynx, and motor nerves for the visceral arch muscles.

DRAWING XXXVI. The cranial nerves and the brain. Draw and label only the nerves actually seen:

(1) a. olfactory nerve
   b. olfactory bulb
   c. olfactory tract
   d. olfactory lobe
(2) optic nerve
(3) oculomotor nerve
(4) trochlear nerve
(5) a. trigeminal nerve
   b. superficial ophthalmic branch
   c. deep ophthalmic branch
   d. maxillary branch
   e. mandibular branch
(6) abducens nerve
(7) a. facial nerve
   b. buccal branch
   c. superficial ophthalmic branch
   d. hyomandibular trunk
   e. geniculate ganglion
   f. palatine branch
(8) auditory nerve
(9) a. glossopharyngeal nerve
   b. petrosal ganglion
   c. branches to mouth and visceral pouch
(10) a. vagus
   b. lateral line branch
   c. visceral branch
      (1) four branches to visceral pouches
      (2) branch to viscera

Phylum, CHORDATA
Subphylum, VERTEBRATA
Class, AMPHIBIA
Order, ANURA
Rana pipiens, the Leopard Frog

EXTERNAL CHARACTERS

Although in many respects the frog is intermediate between fishes and higher vertebrates, its external form is primarily an adaptation to terrestrial life. The paired appendages are similar to those of typical land vertebrates. The adult frog has lungs, and the visceral skeleton is reduced, as it is in higher vertebrates. The middle ear, which is present in the frog, is characteristic of air-breathing vertebrates.

The large *terminal mouth* is provided with close-fitting jaws which prevent the loss of air during pulmonary respiration. The anus lies at the posterior end of the trunk.

The *nostrils,* or *external nares,* are olfactory and respiratory openings. They are located on the dorsal surface of the snout, where they may be conveniently used when the frog is in water. Each opening is provided with a special valve which is closed during the act of inspiration. It may also be closed to prevent the entrance of foreign materials into the nasal cavity.

The *eyes* are protected by an upper and a lower lid. The upper lid has little movement and is covered by a pigmented epidermis, which is a continuation of the outer layer of the skin. The lower lid is semi-transparent and is movable.

The *frontal organ,* a vestige of a median eye, can usually be seen between the paired eyes. In the tadpole this organ is connected with the pineal body, an outgrowth of the roof of the thalamencephalon.

The *tympanic membrane* lies behind the eye. It is the outer wall of the middle ear, which is one of the characteristics of land vertebrates. Near the center of the tympanum is a small elevation which marks the attachment of the columella, a slender bone which extends from the tympanic membrane into the middle ear.

The *fore limb*, or *arm*, is composed of four parts, which are common to all typical land vertebrates: upper arm, forearm, wrist and hand. The hand bears four well developed fingers, with the rudiment of a thumb on the median side. During the breeding season the first finger of the male is usually somewhat swollen.

The *hind limbs* are long and muscular. They are the chief organs of locomotion. Each includes a thigh, a shank, an elongated ankle and a foot with five well developed toes. A rudimentary sixth toe is present on the median side of the foot. The web between the toes makes the foot an efficient swimming organ.

Drawing I. A dorsal view of the entire animal. Label:

(1) head
(2) trunk
(3) anus
(4) nostrils
(5) eyes
(6) frontal organ
(7) tympanic membrane
(8) parts of fore leg
(9) parts of hind leg

Drawing II. A lateral view of the head. Label the parts of the head named in the foregoing list.

The Skeleton

General Characteristics. The skeleton of the frog shows many adaptations to terrestrial life. Bones are formed to give both strength and lightness, although a considerable amount of cartilage remains. The appendicular skeleton is highly developed for locomotion on land. The visceral skeleton is modified and reduced because of the loss of gills, but the modified mechanism plays an important part in the pulmonary respiration of the adult frog. Ribs, which form an essential part of the respiratory mechanism of higher vertebrates, are wanting in the frog.

The skeleton contains two kinds of bones: *cartilage bones*, performed in cartilage, which is gradually replaced by bone; and *membrane bones* which are formed in connective tissues. Obtain a dry skeleton from the instructor and identify its parts.

THE SPINAL COLUMN

How many vertebrae do you find? The first is the atlas, which articulates with the exoccipital bones of the skull. The last typical vertebra articulates with the iliac bones of the pelvis and is called the sacral vertebra. Posterior to it is the slender *urostyle*. Examine the second or third vertebra and identify its parts: centrum, neural arch, neural spine, transverse processes, anterior and posterior articular processes. The centrum is concave in front, convex posteriorly.

DRAWING III. a. Anterior view of a vertebra. Label the parts which are visible. b. Lateral view.

DRAWING IV. Posterior view of the atlas.

THE SKULL

General Structure. The skull of the frog includes the cranium, and the visceral skeleton. In the larval frog, as in the dogfish, the skull is composed of cartilage, and a complete visceral skeleton is present. In the adult frog the skull is modified (1) by the formation of cartilage bones which replace a considerable part of the cartilage, (2) by the addition of membrane bones, (3) by the reduction and modification of the visceral skeleton. (4) In both larval and adult frogs the upper jaw is united with the cranium.

In the adult frog large parts of the cranial wall, ear capsule and nasal capsule consist of cartilage, some of which is exposed to view, while other areas are covered by membrane bones. In the region of the upper jaw, the pterygoquadrate cartilage forms a complete arch, whose posterior end is united with the ear capsule, its anterior end, with the nasal capsule. It is largely concealed by membrane bones. In the lower jaw, Meckel's cartilage persists except at the anterior end, where it is replaced by two small cartilage bones (mento-meckelian bones). Posteriorly Meckel's cartilage has a sheath of membrane bones, but the cartilage is exposed at the angle of the mouth, where it articulates with the quadrate cartilage of the upper jaw. The hyoid apparatus is composed of cartilage, excepting the posterior horns, which are cartilage bones.

Observe the general form and structure of the skull and

locate the nasal capsule, orbit, ear capsule, and foramen magnum, a large opening at the posterior end. The cranial and visceral parts will be studied separately. The parts of the chondrocranium will not be seen in the dried skull.

The Cranium. Both cartilage and membrane bones are present.

Cartilage bones. These are small inconspicuous bones which are closely associated with parts of the chondrocranium. They include two *exoccipitals,* one on each side of the foramen magnum; two *prootics,* one on each side, in the wall of the ear capsule anterior to the exoccipitals; a single *ethmoid,* a ring of bone which encircles the anterior part of the cranium. Each exoccipital bone has a knob, or *condyle,* which articulates with the atlas.

Membrane bones. On the dorsal surface are two large *fronto parietals,* which lie anterior to the exoccipitals; two *nasals,* which extend laterally from the roof of the nasal capsule to the upper jaw. In the floor of the cranium may be seen the large T-shaped *parasphenoid,* whose anterior end overlaps the ethmoid; two *vomers,* small tooth-bearing bones which lie in the floor of the nasal capsules anterior to the palatines.

The Visceral Skeleton. Upper and lower jaws, the hyoid apparatus and the cartilages of the larynx are included in the visceral skeleton. The larynx will be studied in connection with the respiratory system.

The upper jaw. The bones of the upper jaw may be divided into an inner and an outer series. The *outer series* includes, in each half jaw, a small, toothed *premaxilla* at the anterior end; a slender *quadratojugal* at the posterior end; a large tooth-bearing *maxilla* between these two bones. The *inner series* is composed of the *palatine,* which extends across the floor of the skull from the ethmoid to the maxilla; the *pterygoid,* which extends from the floor of the ear capsule to the lateral part of the jaw; the *squamosal,* which lies in the roof of the skull above the pterygoid. The squamosal forms a support for the tympanic cartilage, to which the tympanic membrane is attached. The bones of the upper jaw are membrane bones, excepting the posterior end of the quadratojugal, which is a cartilage bone.

The *lower jaw* consists of two segments on each side: a short anterior segment of cartilage bone, the *mento-meckelian bone;* and a long posterior segment which includes Meckel's cartilage and a sheath of membrane bone formed by the *angular* and the *dentary*. The angular is posterior.

The *hyoid apparatus* is a single plate of cartilage with two horns, or *cornua,* on each side. The anterior horns are slender processes which extend dorsally and are attached to the prootic bones. The posterior horns are small cartilage bones which form a support for the larynx, which lies between them. The body and anterior processes of the hyoid apparatus are derived from the skeleton of the second visceral or hyoid arch. The posterior horns are products of the third visceral arch (first branchial.

Drawing V. A dorsal view of the cranium and upper jaw. Label:

(1) exoccipital
(2) prootic
(3) frontoparietal
(4) ethmoid
(5) nasal
(6) maxillary
(7) premaxillary
(8) quadratojugal
(9) tympanic
(10) pterygoid

Drawing VI. A ventral view of the cranium and upper jaw. Label the parts shown in the preceding drawing so far as they are visible; and in addition, the parasphenoid, palatines, vomers and parts of the cartilaginous cranium, if they can be seen.

Drawing VII. A dorsal view of the lower jaw. Label:

(1) angular
(2) dentary
(3) the mento-meckelian bone
(4) Meckel's cartilage

Drawing VIII. The hyoid apparatus. Label the parts described.

APPENDICULAR SKELETON AND STERNUM

Since the ribs are wanting in the frog, the sternum and pectoral girdle form the only skeletal support for the sides and ventral wall of the trunk region of the body. Within the area thus protected lie the heart and other delicate organs.

a. The *pectoral girdle* is composed of similar halves which are joined together in the mid-ventral line. Each half includes a scapular and a coracoid portion. The former is composed of the *suprascapula,* whose free margin is composed of cartilage; and a bony *scapula,* whose ventral end assists in forming the *glenoid cavity,* a cup-shaped depression which receives the

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head of the humerus. The coracoid portion of the girdle includes a stout *coracoid bone* and a slender *clavicle*. The latter, which is a membrane bone, covers the *procoracoid cartilage*, which is continuous with other cartilaginous remnants at the median and lateral ends of the coracoid portion of the girdle. The median cartilage is a narrow strip called the *epicoracoid*, which joins its fellow in the median line and thus unites the two halves of the girdle.

b. The *sternum* consists of two parts: an anterior *episternum* and a posterior *sternum proper*. Each includes a bony stalk and a large terminal plate of cartilage.

DRAWING IX. The sternum and pectoral girdle. Label:

(1) scapula
(2) suprascapula
(3) coracoid
(4) clavicle
(5) sternum
(6) episternum

c. Compare the skeleton of the fore leg with that of the human arm. The frog's limb has five divisions: (1) an upper division, the *humerus*, which articulates above, with the pectoral girdle; (2) the *radio-ulna*, a single bone, resulting from the fusion of the radius and the ulna; (3) six *carpal bones*, arranged in two rows; (4) five *metacarpals*, whose proximal ends articulate with the carpals, and (5) the *phalanges*, small bones of the fingers. The supporting bone of the rudimentary thumb is a metacarpal. It has no phalanges.

DRAWING X. The fore leg. Label:

(1) humerus
(2) radio-ulna
(3) carpals
(4) metacarpals
(5) phalanges

d. The *pelvic girdle* consists of three bones on each side, the ilium, the ischium, and the pubis. The *ilium* is a long bone, the anterior end of which articulates with the ninth vertebra. The posterior end forms a suture (immovable joint) with its fellow of the opposite side. This part of the bone forms the anterior part of the *acetabulum*, a depression which receives the head of the femur. The *ischium* and *pubis* are small bones which aid in the formation of the acetabulum and the median portion of the pelvis. The ischium is the larger posterior bone. The pubis is small, triangular and ventral in position. The

ischia and pubic bones of the two sides unite in the mid-line. Find the sutures between the bones of the girdle.

The urostyle, a continuation of the vertebral column, extends backward between the two ilia.

DRAWING XI. The pelvic girdle. Label:

(1) ilium
(2) ischium
(3) pubis
(4) acetabulum

The skeleton of the *hind leg* includes five divisions, (1) the *femur,* (2) the *tibio-fibula,* formed by the fusion of the tibia and fibula, (3) the *tarsus,* (4) the *metatarsus,* and (5) the *phalanges.* There are five tarsal bones. Two of these, a median *astragulus* and a lateral *calcaneum* form a proximal row of bones, which articulate with the tibio-fibula. Three small bones form the distal row. The foot has five complete digits, and a small accessory digit which lies on the median side of the foot. Each of the five complete digits consists of a *metatarsal* and from two to four phalanges. The accessory digit has from one to three parts.

DRAWING XII. The hind leg. Label:

(1) femur
(2) tibio-fibula
(3) astragulus
(4) calcaneum
(5) metatarsals
(6) phalanges

THE VOLUNTARY OR SKELETAL MUSCLES

In the adult frog the skeletal muscles are adapted primarily to life on the land. The axial muscles are reduced and modified. Paired appendages are the chief organs of locomotion and the appendicular muscles are greatly developed.

Remove the skin from the body without injuring the muscles. Note the abundant supply of blood vessels to the skin, and the large lymph spaces which lie under it. The spaces are separated by membranous septa which attach the skin to the underlying parts and carry the blood vessels. The removal of the skin exposes the external muscles.

Observe the conspicuous appendicular muscles in the pectoral region. On the ventral surface is a group of *adductor muscles,* which pull the arm ventrally toward the median line.

Above the articulation of the arm is a group of *abductor muscles* which draw the arm away from the middle line. Posterior to the pectoral region some of the *axial muscles* of the trunk are exposed. The dorsal axial muscles are covered by a sheet of connective tissue, the *dorsal fascia,* which extends from the head to the posterior end of the pelvis. Remove a part of the fascia anterior to the pelvic girdle and expose parts of these axial muscles, which retain with slight modification the primitive segmentation. Anterior to the muscles of the pectoral region the superficial muscles of the visceral skeleton may be seen. Representative muscles from different groups will now be studied more closely.

THE MUSCLES OF THE VENTRAL SURFACE

The *submaxillaris* is a thin sheet of muscle whose fibers extend transversely between the two halves of the lower jaw. It raises the floor of the mouth.

The *subhyoid* is a narrow muscle, continuous medially with the posterior part of the mylohyoid and forming apparently a part of that muscle. The lateral end of the subhyoid, however, arises from the anterior horn of the hyoid cartilage close to the cranium.

The *deltoid* muscle lies behind the posterior end of the lower jaw. It arises from the sternum and shoulder girdle and is inserted on the humerus. It pulls the arm forward.

The *pectoralis* is a large muscle consisting of three parts, two of which arise from the sternum and median part of the pectoral girdle, while the third part arises from the wall of the abdomen. All parts unite laterally and are inserted on the humerus. This muscle is the great adductor of the arm.

The *rectus abdominis* is a segmented muscle which extends from the sternum to the pubis. It is divided by a median seam of connective tissue called the *linea alba,* and is covered by a sheet of connective tissue, the *ventral fascia.* The rectus abdominis compresses the abdomen.

The *external oblique* is a continuous sheet of muscle which arises from the ilium and the dorsal fascia and inserts on the ventral fascia. Its fibers extend downward and backward. It constricts the abdomen.

The *transversus* resembles the external oblique in origin, insertion and function. Its fibers extend downward and forward.

DRAWING XIII. Muscles of the ventral surface. Label:

(1) submaxillaris
(2) subhyoid
(3) deltoid
(4) pectoralis
(5) rectus abdominis
(6) ventral fascia
(7) external oblique
(8) transversus

The Deep Muscles of the Floor of the Mouth. Carefully remove the submaxillaris and expose the deep muscles of the floor of the mouth.

The *submentalis* is a short transverse muscle which lies in the angle between the halves of the lower jaw. It raises the tip of the jaw against the premaxillary bones and thus assists in closing the external nares.

The paired *geniohyoid muscles* extend from the lower jaw to the hyoid cartilage. They pull the hyoid forward and assist in raising the floor of the mouth. If the submentalis is relaxed the geniohyoids depress the tip of the lower jaw and open the external nares.

The paired *sternohyoid muscles* are in part continuations of the rectus abdominis, but a part of each muscle arises from the sternum. They are inserted on the body of the hyoid, which they pull backward and downward. They are antagonists of the submaxillaris and geniohyoids.

The *omohyoid* arises on each side from the ventral part of the scapula and is inserted on the body of the hyoid. The two muscles raise the hyoid and the floor of the mouth.

The *petrohyoids* are four small muscles which arise from the lateral portion of the ear capsule and are inserted on the body and posterior horn of the hyoid. They raise the floor of the mouth. To find these muscles, remove the connective tissue lateral from the geniohyoid. The anterior petrohyoid is the largest.

DRAWING XIV. Deep muscles of the floor of the mouth. Label the muscles mentioned above.

Muscles of Mastication. Several muscles are used to open and close the mouth. Only the outer, more conspicuous muscles

will be described. All are supplied by the mandibular branch of the trigeminus, excepting the depressor mandibulae which is innervated by the facial nerve.

The *depressor mandibulae* lies behind the tympanic membrane. It arises from the dorsal fascia and from the tympanic bone and is inserted on the posterior end of the lower jaw. It opens the mouth.

The *masseter major* arises from the tympanic bone and from the ring-like tympanic cartilage. It is inserted on the angular bone of the lower jaw. It closes the mouth.

The *temporalis* is a large muscle which lies under the masseter major. It arises from the prootic and tympanic bones and is inserted on the angular bone of the lower jaw. It closes the mouth.

Muscles of the Ventral Surface of the Hind Leg. These muscles may be divided into different groups according to their function: *adductors,* which draw the entire leg toward the median ventral line; *abductors,* which pull the entire leg away from the median ventral line; *flexors,* which bend the entire limb on the body, or one part of the limb on another; *extensors,* which straighten the limb or its parts. By combining muscles of different groups, a great variety of movements may be produced. Study the muscles of the ventral surface.

The *sartorius* is a band-like muscle which extends along the middle of the thigh. It arises from the ventral part of the ilium and is inserted with other muscles on the upper end of the tibio-fibula. It flexes the shank and adducts the entire leg.

The *triceps femoris* is a large muscle which forms the anterior lateral border of the thigh. It arises from the pelvic girdle by three heads, a dorsal, a lateral and a ventral, which unite posteriorly to form a single body. Its posterior end is inserted by a flat tendon on the upper end of the tibio-fibula. This muscle extends the shank and flexes the thigh on the body. Demonstrate these functions.

The *adductor longus* is a narrow muscle which is more or less covered by the sartorius. It arises from the posterior ventral part of the ilium; distally it joins the next muscle.

The *adductor magnus* is a thick muscle which arises from the

pubis and ischium and is inserted on the distal end of the femur. What is its function?

The *gracilis major* and *gracilis minor* form the posterior median border of the thigh, the major being covered in part by the minor. They extend from the ischium to the knee. They adduct the leg and flex the shank.

The *gastrocnemius,* which forms the calf of the leg, is a large muscle which arises from the distal end of the femur. The lower end tapers to a strong tendon, the *tendon of Achilles,* which passes over the ankle and terminates in a broad fascia which covers the sole of the foot. Determine the function of this muscle.

The *tibialis anticus longus* lies opposite the gastrocnemius on the outer lateral border of the shank. It arises from the lower end of the femur and is inserted on the proximal ankle bones. What is its function?

The *tibialis posticus* is a slender muscle which lies between the gastrocnemius muscle and the shank bone. Its function is the same as that of the gastrocnemius.

Drawing XV. Muscles of the ventral surface of the leg. Label the muscles which are visible.

The Digestive System

Open the mouth widely and find the tongue, glottis, oesophagus, choanae, or internal nares, and Eustachian tubes. Vocal sacs are present in the male. The mouth is lined with ciliated epithelium.

Make a longitudinal incision through the body wall a little on one side of the mid-ventral line from the sternum to the pubis. Observe the abdominal vein attached to the inner surface of the body wall in the middle line. Cut short transverse incisions in the body wall behind the sternum and anterior to the pubis, and expose the contents of the *body cavity,* or *coelom.* The abdominal vein should be preserved.

The *digestive system* includes the mouth, pharynx, oesophagus, stomach, small intestine, large intestine, and two glands, the pancreas and liver. The mouth and pharynx have been studied. The *oesophagus* opens into the enlarged cardiac end

of the *stomach,* whose narrow posterior part is the pyloric region. The opening from the stomach into the intestine is the *pylorus,* which can be closed by a ring of smooth muscle. The anterior part of the intestine is the *duodenum,* which is followed by a long, coiled, small intestine. A short large intestine or *colon* opens into the cloaca. Compare the intestine of the frog with that of the dogfish.

Observe the *mesenteries* which extend from the mid-dorsal region to the alimentary canal. In the mesentery of the large intestine is the *spleen,* one of the lymphatic organs. The pancreas lies in the hepato-duodenal ligament, a small mesentery which extends from the liver to the duodenum. The pancreatic ducts open into the bile duct.

The *liver* has three lobes, two large lateral lobes and a small median lobe. The gall bladder lies on the dorsal surface of the liver between the right and left lobes. The bile duct runs through the hepato-duodenal ligament to the duodenum. The duct may be made visible by pressing on the gall bladder.

Drawing XVI. The digestive system. Label the following parts:

(1) oesophagus
(2) stomach
(3) pylorus
(4) duodenum
(5) small intestine
(6) large intestine
(7) mesenteries
(8) liver
(9) gall bladder
(10) pancreas
(11) bile duct
(12) abdominal vein

The Circulatory System

The circulation of the frog differs greatly from that of the dogfish. In the latter the blood passes first through the respiratory organs and from these directly into the systemic blood vessels. In the adult frog the blood which passes through the respiratory organs must return to the heart before it is sent out to the body. Thus we can distinguish a pulmonary and a systemic circulation, although the two are intimately related.

The Heart

Cut through the pectoral girdle on each side of the median line. Remove the isolated part of the girdle and the underlying

sternohyoid muscle and locate the heart, which is covered by the pericardium.

Remove the pericardium and identify the thick-walled conical *ventricle* and the *two auricles* which lie anterior to it. From the base of the ventricle, on the right side, arises the *conus arteriosus,* which divides into two trunks, a right and a left ventral aorta. Lift the ventricle and find the thin-walled *sinus venosus,* which receives the blood from the body.

A pulmonary vein bringing blood from the lungs, enters the dorsal wall of the left auricle. What kind of blood does the ventricle contain? Compare the heart of the dogfish.

In a frog prepared by the instructor, study the heart cycle or wave of contraction which passes from one end of the heart to the other.

THE ARTERIAL SYSTEM

The arterial system of the frog larva is similar, in a general way, to that of the dogfish. In the branchial region of both forms, the ventral and dorsal aortae are connected by aortic arches consisting of afferent arteries, gill capillaries and efferent arteries. Of the six pairs of primitive arches common to the vertebrates, there are four in the tadpole (the third to the sixth) and five in the dogfish (the second to the sixth). In the adult frog certain parts of this system disappear; the third pair gives rise to the carotids; the fourth forms the systemic arches; the fifth pair disappears; the ventral parts of the sixth pair form the proximal ends of the pulmo-cutaneous arteries.

The Aortic Arches. Study the ventral aorta and identify the branches named above. The *anterior branch* divides to form the internal and external carotids which carry blood to the head.

The *middle* or *systemic arch* passes dorsal to the oesophagus, where it unites with its fellow to form the dorsal aorta. Each systemic arch gives branches to the larynx, oesophagus and spinal column, and a subclavian artery to the shoulder and arm.

The *third branch* of the ventral aorta is the *pulmo-cutaneous artery.* It divides to form the *pulmonary artery* which passes to the lungs, and the *cutaneous artery* which carries the impure blood to the skin for aëration.

The Dorsal Aorta. Find the following branches:

The *coeliaco-mesenteric artery* arises from the dorsal aorta near the junction of the two aortic arches. It has two branches, a *coeliac artery* which supplies liver, stomach and pancreas; and an *anterior mesenteric artery* which carries blood to the small intestine, colon, spleen and cloaca.

Urogenital arteries, four to six in number, arise from the ventral surface of the aorta and supply the gonads, fat bodies and excretory organs.

Lumbar arteries, one or more pairs, supply the muscles of the body wall in the region of the urogenital organs.

A *posterior mesenteric artery* distributes blood to the colon.

Two *iliac arteries,* formed by the division of the dorsal aorta, pass into the legs.

Drawing XVII. The heart and arteries. Label the parts which you are able to identify:

(1) chambers of heart
(2) conus arteriosus
(3) ventral aorta
(4) carotid arch
(5) systemic arch
(6) pulmo-cutaneous arch
(7) dorsal aorta
(8) coeliaco-mesenteric artery
(9) coeliac artery
(10) anterior mesenteric artery
(11) urogenital arteries
(12) lumbar artery
(13) posterior mesenteric artery
(14) iliac artery
(15) pulmonary artery
(16) cutaneous artery

THE VENOUS SYSTEM

The venous system of the early frog larva is similar to that of the dogfish. In later larval stages of the frog the two post-cardinals degenerate and a single postcava is formed, which receives the greater part of the blood from the posterior part of the body. The Cuvierian ducts and the precardinals of the larva form the two precavae of the adult. The venous system of the adult frog includes pulmonary veins, the systemic veins, the renal portal system and the hepatic portal system.

The Pulmonary Veins. These veins carry pure blood from the lungs to the left auricle. The two veins unite at the base of the left *precava,* from which point a single vessel passes to the heart.

The Renal Portal System. The blood from the posterior part of the body is collected by two renal portal veins which run forward along the lateral borders of the kidneys. Each vein is formed by the union of two veins from the hind leg: a *femoral vein* from the anterior lateral part of the thigh, and a *sciatic vein* from the posterior median part of the thigh. From each femoral vein arises a *pelvic vein,* which unites with its fellow to form the *abdominal vein.* On the lateral border of the kidney the renal portal vein receives a *dorso-lumbar* vein from the muscles of the back.

The Systemic Veins. These include three chief trunks: two precaval veins (anterior venae cavae) and a postcaval vein (posterior vena cava). The entrance of these veins into the sinus venosus may be seen by lifting the ventricle. *The postcava* receives blood from the liver, gonads and kidneys and from the wall of the body. It is formed between the kidneys by the union of four to six *renal veins,* which carry forward the blood brought to the kidneys by the renal portal veins. The postcava, therefore, contains a large amount of blood which has been purified by the removal of its nitrogenous waste. From the liver the postcava receives blood through two *hepatic veins,* which join the trunk vein near the sinus venosus.

The *two precavae* enter the lateral angles of the sinus venosus, to which they return the blood from the anterior part of the body. Each precaval vein is formed by the union of three tributaries. The *external jugular,* the most anterior, receives blood from the tongue and floor of the mouth. The second vein, the *innominate,* has two tributaries: the *internal jugular* which carries blood from the head, and the *subscapular vein* which receives the blood from the shoulder. The third tributary of the precava is *the subclavian,* which also has two tributaries, a *brachial vein* from the arm, and a *cutaneous vein,* which returns purified blood from the skin. The cutaneous vein runs forward under cover of the abdominal portion of the pectoral muscle. Follow it as far as you can.

The Hepatic Portal System. In the frog, as in the dogfish, the blood of the digestive organs and spleen is collected by a hepatic portal vein, which carries the blood to the liver. Ob-

serve the larger tributaries of this vein and follow the trunk forward through the pancreas toward the liver. As it approaches the liver the vein divides into two branches, one for each of the large lobes of the liver. The right branch is connected with the abdominal vein, which thus forms a path by which a part of the blood from the hind legs may enter the liver.

Drawing XVIII. A ventral view of the venous system. Label the veins which you have identified:

(1) postcava
(2) precavae
(3) external jugular
(4) innominate
(5) subclavian
(6) sinus venosus
(7) hepatic veins
(8) renal portal
(9) renal veins
(10) femoral vein
(11) sciatic vein
(12) abdominal vein

Flow of Blood through the Web of the Frog's Foot (Demonstration)

Observe the pigment cells in the skin. Below these, small arteries and veins may be seen, and between these, a network of capillaries. Note the direction of the flow in the capillaries. The blood passes from capillaries into the veins. Can you detect a pulse in some of the larger vessels? The transparent part of the blood is the *plasma*. The most abundant cells are the *red blood corpuscles*. *White corpuscles* may also be seen. Compare the diameter of the capillaries with that of the corpuscles. What are the functions of the capillaries? What is the origin of lymph and what are its functions?

Respiration and Respiratory Organs

Respiration of Fishes and Amphibians. The tadpole and other aquatic amphibians have a branchial respiration like that of the dogfish, in which the respiratory currents are maintained by the visceral muscles and skeleton (bucco-pharyngeal mechanism). In the aquatic amphibians the same mechanism is used to force air into the lungs. In the adult frog branchial respiration is lost, but a modified bucco-pharyngeal mechanism

supplies air both for *pulmonary* respiration and for *buccal,* or mouth, respiration.

Respiration in the Frog. The frog, like other typical amphibians, obtains its oxygen supply through lungs, skin and mouth. The skin is a factor in respiration at all times, and during hibernation it is the most important factor, though the mouth may also be used. During periods of activity the mouth is regularly used and pulmonary respiration is intermittent, the length of the intervals depending on exercise, temperature, etc. Study respiration in the living frog.

Buccal respiration is provided for by regular oscillations of the floor of the mouth during the intervals between successive pulmonary acts. In these intervals air enters the mouth through the nostrils and passes out again by the same route, while the glottis remains closed. Oxygen is taken up by the blood vessels of the mucous membrane which lines the mouth and pharynx.

Pulmonary respiration includes three stages. (1) The mouth is filled with air by depression of its floor (aspiration). (2) The glottis opens and the abdominal walls contract to force air out of the lungs (expiration). (3) The external nares close and the floor of the mouth is raised to force air into the lungs (inspiration); as a result of this the abdomen is more or less enlarged. After inspiration is completed the glottis closes and the inspired air remains in the lungs until another act of respiration occurs. On account of its mode of operation the mechanism of pulmonary respiration in the frog has been called a *force-pump mechanism.* Name some of the muscles of this mechanism. Study the operation of this mechanism in the living frog and compare it with the respiratory mechanism of mammals.

The *larynx* is composed of a ring-like *cricoid* cartilage, and two *arytenoid* cartilages which guard the glottis. By the movement of the arytenoids the glottis is opened and closed. Within the larynx are vocal cords which are used in croaking. How does the frog croak under water?

The *lungs* are elastic sacks with pouched walls. Capillaries in the walls of the lungs bring the blood into close relation to the inspired air.

The Closing of the External Nares. The mechanism which closes the nares includes (1) the lower jaw with its adductor muscles; (2) a system of levers at the rostrum, and the submentalis muscle which operates it. The lever system consists of the mento-meckelian bones, the premaxillary bones, and a small cartilage which extends from the premaxillary to the nasal opening. Study again the form and structure of the jaws. The smooth, toothless lower jaw fits into a groove in the upper jaw, and the premaxillaries lie above the mento-meckelian bones. The overhanging upper lip has a smooth muscle which aids in keeping the mouth closed. Observe the living frog and determine the manner in which the nasal openings are closed. Look for evidence of the contraction of the submentalis muscle. Can the frog close the external nares when the mouth is open? Can it fill the lungs when the mouth is open? How are the external nares opened? The salamanders have smooth muscles which open and close the external nares.

The Urogenital System

The Male. With a knife cut through the pelvis in the mid-ventral line between the legs. Carefully separate the severed parts and expose the cloaca and the structures which open into it.

The *kidneys* (*mesonephroi*) are oblong flattened bodies which are attached directly to the dorsal body wall anterior to the cloaca. Each mesonephros is composed of many tubules lined by excretory epithelium which separates salts and urea from the blood. These tubules open into the *Wolffian duct,* or ureter, a straight white tube which extends from the lateral margin of the kidney to the dorsal wall of the cloaca. What is the nature of the excretory process?

On the ventral surface of each kidney is an irregular yellowish gland called the *adrenal body*. It is an *endocrine* organ.

The *urinary bladder* is a thin-walled sack which opens into the cloaca. Urine passes from the cloaca into the bladder, from which it is occasionally expelled.

The *testes* are two small whitish bodies which are attached by short mesenteries to the ventral surface of the kidneys.

From each testis a number of short tubes, *vasa efferentia,* run through the mesentery to the kidney, where they join the mesonephric tubules. Through these tubules the sperms reach the Wolffian duct, by which they are carried to the cloaca.

Vestigial oviducts are present in some male frogs near the lateral border of the kidney.

Anterior to the gonads are two *fat bodies* with a number of finger-like processes. They contain stored food material which is used during the period of hibernation.

DRAWING XIX. The male urogenital system. Label the following:

(1) mesonephros
(2) Wolffian duct
(3) urinary bladder
(4) testes
(5) vasa efferentia
(6) vestigial oviduct, if present
(7) fat bodies
(8) cloaca

The Female. Cut through the pelvis and expose the cloaca, as directed for the male.

The mesonephroi, Wolffian ducts, bladder and fat bodies are like those of the male, but the ducts function only as excretory ducts.

The *ovaries* are attached to the ventral surface of the kidneys. They vary in size and appearance at different seasons. When the eggs are maturing the ovaries are greatly enlarged

The *oviducts* are coiled whitish tubes which extend from the anterior part of the coelom to the cloaca. Each oviduct has a separate mouth, or *ostium,* through which the eggs enter from the coelom. As the eggs pass down the oviduct they are covered by a gelatinous envelope. The posterior part of the oviduct is enlarged to form a *uterus,* a temporary reservoir for the eggs during ovulation. Where does fertilization occur?

Compare the urogenital systems of the dogfish and frog.

DRAWING XX. The urogenital system of the female. Label:

(1) mesonephros
(2) Wolffian duct
(3) bladder
(4) ovary
(5) oviduct
(6) ostium
(7) uterus
(8) cloaca
(9) fat bodies

The Nervous System

The Spinal Nerves. Each spinal nerve arises from the spinal cord by two roots, which unite between the vertebrae to form a single trunk. As it leaves the spinal column the trunk nerve divides into two branches: a *dorsal branch* for the dorsal part of the body wall, and a *ventral branch* for the ventral part of the body wall. Each ventral nerve gives rise to a *visceral branch* which joins the sympathetic system.

Place the frog on its back, lift the digestive organs and kidneys and sever the mesenteries and the coeliaco-mesenteric artery, leaving the dorsal aorta in place. Cut the intestine and urogenital ducts anterior to the cloaca and pull the entire mass of organs forward toward the head. Then sever the aortic arches lateral from the oesophagus and remove the organs by cutting through the posterior end of the pharynx. This operation will expose the ventral branches of the spinal nerves.

These nerves emerge in pairs from the sides of the spinal column through openings called *intervertebral foramina.* How many pairs of nerves do you find? Note the large second nerve and its connections with the first and third nerves. These nerves and their connections form the *brachial plexus,* from which arise the nerves for the arm. A more complicated plexus, *the sciatic,* is formed by the seventh, eighth and ninth nerves, which supply the leg.

The Sympathetic or Autonomic System. The chief part of this system is a pair of ganglionated cords, one of which lies on each side of the spinal column near the aortic arches and the dorsal aorta. Count the ganglia with a hand lens. Each ganglion receives a visceral branch from one of the spinal nerves. Peripheral branches also pass from the ganglia to the viscera. One of the largest of these is the *splanchnic nerve,* which accompanies the coeliaco-mesenteric artery.

Drawing XXI. The spinal nerves and autonomic system. Label the parts which you have seen:

(1) spinal column
(2) spinal nerve, ventral branch
(3) spinal nerve, visceral branch
(4) brachial plexus
(5) sciatic plexus
(6) splanchnic nerve
(7) autonomic system

The Brain and Spinal Cord. Expose the brain by removing the skin and roof of the cranium. Continue the dissection caudally and uncover the spinal cord, which lies in the neural canal surrounded by the vertebrae. The entire central nervous system is covered by two protecting membranes, one of which, the *pia mater,* will probably be found adhering to the surface of the brain and cord. The outer membrane, the *dura mater,* is attached to the wall of the cranium and spinal canal.

Remove the pia mater, if present, and observe the form of the spinal cord. In the dogfish the cord tapers somewhat uniformly from the anterior to the posterior end. In the frog, with its well developed legs, the cord becomes enlarged in those regions which furnish nerves for the appendages. Thus are formed a *brachial enlargement* which supplies the arm, and a *sciatic enlargement* for the posterior appendages. Behind the sciatic enlargement the spinal cord is reduced to a small thread, the *filium terminale,* which enters the urostyle.

The dorsal roots of the spinal nerves should now be seen. Look for the ganglia. The posterior roots, both dorsal and ventral, run for some distance within the neural canal before they leave the spinal column. The entire bundle of elongated roots together with the filium terminale is called the *cauda equina,* or horse's tail.

Compare the brain of the frog with that of the dogfish. The parts of the brain are more distinct in the frog, and the cerebrum is relatively large. The cerebellum is a low transverse fold behind the optic lobes.

Drawing XXII. Dorsal view of spinal cord and brain. Label:

(1) spinal canal
(2) spinal cord
(3) brachial enlargement
(4) sciatic enlargement
(5) medulla
(6) cerebellum
(7) optic lobes
(8) thalamencephalon
(9) cerebrum
(10) olfactory lobes
(11) cauda equina

The ventricles of the brain are similar to those of the dogfish brain. Find the lateral ventricles in the cerebral hemispheres of the frog. Each lateral ventricle opens through a foramen of Monro into the third ventricle, which lies in the thalamencephalon. From the third ventricle the aqueduct of Sylvius

passes through the midbrain and opens into the fourth ventricle, which lies in the medulla. A small optic ventricle in each optic lobe opens into the aqueduct of Sylvius.

Drawing XXIII. The ventricles of the brain.

The Cranial Nerves. In the frog larva the cranial nerves are like those of the dogfish. Both have ten pairs of nerves, including special branches for the lateral line organs; and both have gill clefts which more or less determine the arrangement and branching of the posterior nerves. During the metamorphosis of the frog larva, the lateral line organs and nerves disappear and the loss of the gill clefts involves certain changes in the nerves of the visceral arches. These changes affect particularly the distribution of the facial, glossopharyngeal and vagus nerves.

1. The *olfactory nerve* extends from the olfactory chamber to the olfactory lobe of the cerebrum; it is composed of the axons of neurones which lie in the olfactory epithelium.

2. The *optic nerve* runs from retina to the floor of the thalamencephalon, where the two optic nerves cross, thus forming the *optic chiasma*. The nerve is composed of the axons of neurones which lie in the retina.

Cut away the upper eyelid and the skin above the left eye. The eyeball is held in the orbit by certain muscles and the optic nerve. Cut the nerve and muscles close to the eyeball and remove the latter from the orbit.

3, 4, 6. The *oculomotor, trochlear* and *abducens* are small nerves which enter the orbit and supply the muscles of the eyeball. The oculomotor nerve arises from the floor of the midbrain and innervates four muscles: the superior rectus, inferior rectus, internal rectus and inferior oblique. The trochlear nerve arises from the posterior part of the roof of the midbrain. It supplies the superior oblique muscle. The abducens nerve arises from the floor of the medulla and inervates the external rectus muscle. These muscles will be described in connection with the eye.

5 and 7. The *trigeminus* and *facial* are closely associated in the frog; they have a common ganglion, the *prootic,* which lies within the cranium. The roots of the nerve arise from the

antero-lateral part of the medulla. From the prootic ganglion four nerves pass forward and enter the orbit: (1) the *ophthalmic branch* of the fifth, a sensory nerve, which passes through the median part of the orbit; (2) a *maxillo-mandibular branch* of the fifth, which divides immediately into maxillary and mandibular nerves for the jaws; (3) a *palatine branch* of the seventh nerve which passes through the orbit to reach the roof of the mouth; (4) a *hyomandibular branch* of the seventh nerve which bends backward around the anterior wall of the ear capsule. It supplies the skin and two muscles of the hyoid region: the subhyoid and the depressor mandibulae.

8. The *auditory* supplies the internal ear. It is the nerve of hearing and equilibrium.

9 and 10. The *glossopharyngeal* and *vagus* are closely related near their origin. Both enter a large jugular ganglion which lies behind the ear capsule. The *ninth nerve* leaves the ganglion, forms a small ganglion of its own, and then divides into two branches. One of these joins the hyomandibular branch of the seventh nerve, the other, larger trunk supplies the anterior petrohyoid muscle and furnishes sensory fibers for the tongue and floor of the mouth. The *vagus nerve* leaves the jugular ganglion and bends ventrally, supplying smaller branches to the skin, posterior petrohyoid muscles and laryngeal muscles, while the main trunk divides into branches for the heart, lungs, stomach, etc.

Drawing XXIV. The cranial nerves. Show and label only the nerves which you have identified. Some of the smaller nerves may not be seen.

The Sense Organs

The Olfactory Organ. In the frog the *olfactory chamber* opens into the mouth and becomes a *respiratory passage* through which air may enter and leave the body. This arrangement gives special importance to the *buccal respiration,* which provides for a constant and thorough testing of the respiratory medium.

The olfactory chamber is large and the olfactory epithelium covers a considerable surface. The mechanism which closes

the external nares during inspiration is also used to keep foreign substances out of the nasal cavity. A *naso-lachrymal* duct leads from the eye to the nasal chamber, as in all air-breathing vertebrates.

Olfactory neurones lie in the wall of the nasal cavity and their axones form the olfactory nerve which carries the stimulus to the olfactory lobe of the brain.

The Eye. If the eyeball and its muscles were not studied in the dogfish they may be examined here. Expose the right eyeball by removing the upper eyelid and the adjacent skin. The frog has the usual muscles for moving the eyeball: four *recti muscles* and two *oblique muscles*. In addition to these muscles, the frog has a special muscle, the *levator bulbi,* which raises the eyeball; and a *retractor bulbi* which pulls the eyeball into the orbit. The superior oblique muscle and the super rectus muscle are attached to the dorsal surface of the eyeball. To find the other muscles cut away the lower jaw and remove the mucous membrane below the orbit. This operation will expose the levator bulbi, a broad sheet of muscle which lies below the eyeball. If the levator muscle is cut away, the inferior oblique muscle will be seen ventral to the superior oblique. The recti muscles arise together in the posterior median part of the orbit. The inferior rectus inserts on the ventral surface of the eyeball; the external rectus, on its posterior surface; the internal rectus, on its anterior surface between the two oblique muscles. The retractor bulbi arises in the posterior part of the orbit and is inserted on the median surface of the eyeball.

Examine the outer part of the eyeball and identify the transparent cornea; the opaque sclera, which covers the deeper part of the eyeball; the pigmented iris, which lies behind the cornea in the interior of the eyeball. Cut away the dorsal portion of the eyeball. The wall of the eyeball has *three layers:* an outer layer, which includes the cornea and sclera; the pigmented choroid, which is continuous with the iris; the inner nervous layer, or retina. Observe the lens, which lies behind the pupil. The lens and iris divide the internal cavity of the eyeball into an *internal chamber* which lies behind the iris and lens, and an *external chamber* which lies between the cornea and iris. The

external chamber is filled with *aqueous humor,* the internal chamber with the jelly-like *vitreous humor.*

The lens is almost spherical and is attached by special fibers to thickenings of the choroid coat, called *ciliary processes.* A mechanism for adjusting the eye to near and far objects is said to be wanting in the frog. Only near objects can be clearly seen. The iris has a smooth muscle which contracts the pupil and regulates the amount of light which enters the eye.

The Ear. In the frog the ear includes two parts: an *inner ear* and a *middle ear,* or tympanum. The latter is a cavity which opens into the mouth through the Eustachian tube; it is formed during and after the metamorphosis from the first visceral cleft of the larva. The outer wall of this cavity becomes the *tympanic membrane;* its inner wall contains two smaller membranes which separate the middle ear from the internal ear. The smaller membranes close two openings called the *fenestra ovalis* and the *fenestra rotunda.* A sound-transmitting apparatus, consisting of a rod-like *columella* and a plate-like *stapes,* extends from the tympanic membrane to the membrane of the fenestra ovalis.

Cut around the margin of the tympanic membrane and find the columella attached to its inner surface. The stapes is inserted in the fenestra ovalis. Note the wide Eustachian tube which leads from the tympanic cavity to the mouth.

What is the function of the middle ear? What bones perform the function of the columella in man?

The inner ear is similar to that of the dogfish, but the endolymphatic duct of the frog does not have an external opening.

Histology of the Frog

The Skin. The *skin* of the frog includes an outer ectodermal layer, the *epidermis,* and an inner mesodermal layer, the *dermis* or *cutis.* The epidermis consists of several layers of cells. The outer layers form a *horny stratum* which is occasionally molted; they are replaced by additions from the deeper layers, the *germinal stratum,* which is constantly renewed by cell division. From the epidermis arise flask-shaped *glands* which open on the surface of the skin. They are lined

by a layer of *secreting cells*. Mucous and poison glands are present. The dermis is a dense layer of connective tissue containing nerves and blood vessels. Both dermis and epidermis contain *pigment cells* which give color to the skin. Under the skin are large lymph spaces in which water is stored.

The skin protects the body; it is a sense organ, and an important respiratory organ. It is the special function of the epidermis to control the exchanges which occur between the body and the outside world. This is possible, however, only so long as the frog remains in a moist environment. In dry air the skin loses water and the animal dies.

Drawing XXV. A section of the skin. Label:

(1) epidermis
(2) horny stratum
(3) germinal stratum
(4) dermis
(5) pigment
(6) glands
(7) duct of gland
(8) secreting cells of gland

The Stomach. The following layers may be distinguished in the wall of the stomach: the mucous membrane, the submucosa, the muscle layer, and the peritoneum.

The *mucous membrane* is composed of (a) an inner epithelium which lines the cavity and forms numerous glands; (b) connective tissue, which fills the spaces between the glands; (c) a delicate layer of smooth muscle called the muscularis mucosa. The glands of the stomach are small tubular glands which frequently branch. They extend from the surface of the stomach into the connective tissue of the mucous membrane. The deeper parts of the glands are lined with secreting cells. Pepsin is produced chiefly by the glands of the cardiac region of the stomach.

The *submucosa* is a layer of connective tissue which lies between the mucous membrane and the muscle layer.

The *muscle layer* is composed chiefly of a circular stratum of smooth muscle fibers, but at the ends of the stomach a weak stratum of longitudinal fibers is present. Contraction of the muscles of the stomach keeps the food in motion during digestion and empties the stomach after digestion is completed.

The *peritoneum,* which consists of pavement epithelium and

a thin stratum of connective tissue, forms the outer layer of the stomach.

Drawing XXVI. The structure of the frog's stomach.

The Liver. The external covering of the liver is a layer of peritoneum, which is composed of a simple pavement epithelium and connective tissue. From the peritoneum, connective tissue also enters the interior of the organ. The liver is a much branched *tubular gland,* the terminal twigs of which are called the *hepatic cords.* Close examination will show that these cords are actually tubules, the small central canals being the *bile capillaries.* The walls of the cords are *hepatic cells,* from two to six of which may be seen in cross sections of the cords. Observe the form and structure of the hepatic cells. They yield a secretion called *bile,* which is poured into the bile capillary. Between the hepatic cords are *blood capillaries,* which may be recognized by the blood corpuscles which they contain. These capillaries receive blood from the hepatic portal vein which carries to the liver the sugar which is obtained from the digestive tract. The hepatic cells change the sugar into granules of *glycogen* which is stored in the cells for future use.

Drawing XXVII. The structure of the liver.

The Kidney. The kidney is composed of coiled *uriniferous tubules,* which are lined with excretory epithelium. The tubules separate nitrogenous waste and mineral salts from the body fluids. Each tubule begins with a spherical *Malpighian body,* which consists of an outer capsule which opens into the tubule, and an inner glomerulus which projects into the tubule but does not entirely fill it. The glomerulus is fed by a small artery and is drained by a small vein. Water and dissolved materials pass from the glomerulus into the capsule and thence into the tubule. The uriniferous tubules open into *collecting tubules* which run transversely from the median margin of the kidney to the *ureter.* The kidney has an abundant supply of blood vessels, including networks of capillaries which infest the uriniferous tubules. The blood supply comes in part from the renal portal veins, in part from the renal arteries which are branches of the dorsal aorta.

Drawing XXVIII. The structure of the kidney.

Identification of Tissues and Organs. Name tissues and organs in the following sections:

DRAWING XXIX. Section of salamander larva through mid-dorsal region.

DRAWING XXX. Section of head of young bullfrog.

Phylum, CHORDATA
Subphylum, VERTEBRATA
Class, REPTILIA
Order, TESTUDINATA
Superfamily, CRYPTODIRA

The Turtle

The turtle is a greatly modified reptile, but in spite of its peculiarities, it has many characteristics which are common to the entire class Reptilia. Among these characters are a dry scaly skin, a cloaca, cold blood, two aortic arches, twelve cranial nerves, a metanephros, large eggs which are fertilized internally, special embryonic membranes, and a type of development which carries the embryo to the adult form before it leaves the egg. How many of these characteristics do amphibians share with reptiles?

For the following study, any one of the common hard-shelled turtles may be used. If the laboratory is not provided with skeletons of the turtle, two specimens will be required for the complete dissection. It is assumed that the student is familiar with the structure of the dogfish or frog.

THE SKELETON

The turtle has an *endoskeleton* and an *exoskeleton.* The endoskeleton consists of axial and appendicular divisions, the former including the skull, spinal column and ribs; the latter, the pectoral and pelvic girdles and the skeleton of the legs. The shell receives contributions from both endoskeleton and exoskeleton.

THE SHELL

Observe the two divisions of the shell: the dorsal *carapace* and the ventral *plastron,* which are joined by a narrow bridge on each side. Elsewhere they are separated by a narrow space

which permits the extension and retraction of the head, appendages and tail. In some species, such as the box turtle (*Terrapene carolina*) and Blanding's turtle (*Emys blandingii*), a transverse hinge across the middle of the plastron permits a more or less complete closing of the shell.

Study the *structure* of the *shell.* The outer layer consists of large horny epidermal plates, or *scutes;* the inner layer is composed of bony plates formed by endoskeleton and exoskeleton. Do the outer and inner plates correspond in size and number? In some turtles the epidermal plates show distinct lines of growth.

The *bony layer* of the carapace includes (a) eleven *median plates,* eight of which, called *neural plates,* are fused with the neural arches of the vertebrae; (b) a row of *costal plates* which are fused with the ribs on each side; (c) a row of *marginal plates,* which form a complete ring around the edge of the shell. Anterior to the neural plates is a large *nuchal plate;* behind the neurals are two *postneural plates.*

The *plastron* is composed of six pairs of epidermal scutes and nine bony plates. The first pair of the latter may represent clavicles; the median plate is called the *interclavicle.*

DRAWING I. The outer surface of the carapace.

THE SPINAL COLUMN

Note the four groups of vertebrae: eight cervical, ten dorsal, two sacral and several caudal. Study the cervical vertebrae. The first is the atlas, a ring-like bone whose anterior surface articulates with the skull. The second vertebra is the axis, which forms a pivot joint with the atlas. Determine the nature of this joint and compare the articulation of the atlas and axis in the mammals. Study the other cervical vertebrae and their articulations, also the articulation between the posterior cervical vertebra and the first dorsal. What are the parts of a typical vertebra? The neural arches of the ten *dorsal vertebrae* are fused with the carapace. The *sacral* and *caudal vertebrae* are free. Observe that the caudals have both neural and haemal arches.

DRAWING II. The inner surface of the carapace, with dorsal and sacral vertebrae. Label the parts described.

THE SKULL

Locate the external naris, the choanae or internal nares, the orbital fossa, the tympanic fossa or middle ear cavity, and the occipital foramen. Note the solid construction and compact form of the skull. The bones of the upper jaw and cranium are immovably united. The cranium and visceral skeleton will be studied separately.

The Cranium. The cranial bones form the greater part of the roof and posterior end of the skull. The foramen magnum is surrounded by three cranial bones: a right and left *exoccipital* and a dorsal *supraoccipital.* From the last a strong spine projects backward above the foramen magnum. Below the exoccipitals lies a single *basioccipital,* which joins the exoccipitals in forming a knob, the *occipital condyle.* What is the function of this condyle?

On the roof of the skull, between the supraoccipital and the external naris, lie the paired *parietals, frontals* and *prefrontals.* Nasals are wanting in the turtle. Lateral to the supraoccipital and parietal, on each side, is the ear capsule, the roof of which is formed by two small otic bones: an anterior *prootic* and a posterior *opisthotic.* Lateral to the frontal, and behind the orbit, is the *postfrontal.* Other bones which are visible in a dorsal view belong to the visceral skeleton and will be described below.

The floor of the cranium includes only an incomplete series of median bones: the *basioccipital,* which has been described; the *basisphenoid,* which lies anterior to the basioccipital; the *vomer,* which lies behind and between the choanae. Certain parts of the chondrocranium persist in the adult turtle but these will not be found in the dry skull.

The Visceral Skeleton. The skeleton of the jaws and the hyoid apparatus will be described here. The bones of the middle ear will be considered in connection with the ear.

a. *The upper jaw.* The bones of the *upper jaw* form the anterior and lateral walls and the greater part of the floor of the skull. In the floor, where these bones may be readily seen, they include an inner and an outer series on each side.

The *outer series* of bones forms the anterior and lateral boundaries of the skull. The most anterior bone of the series is the *premaxilla,* which lies ventral to the external naris. The *maxilla* forms the lateral wall of the skull behind the premaxilla. In the natural condition of the skull these two bones are partly covered by the horny upper jaw. The *jugal* lies posterior to the maxilla and ventral to the postemporal. The jugal is followed by the *quadratojugal,* which extends to the anterior margin of the auditory fossa, where it joins the quadrate. Above the fossa the quadratojugal meets the *squamosal,* which forms the postero-lateral angle of the skull.

The *inner series* of upper jaw bones is composed of the quadrate, pterygoid and palatine. The *quadrate* forms a large part of the wall of the auditory fossa, ventral from which it articulates with the lower jaw. The broad *pterygoid* lies on the median side of the quadrate and forms a part of the cranial floor. The *palatine* extends forward from the pterygoid to the palatine portion of the maxilla.

b. *The lower jaw.* The chief bones of the lower jaw are the *articular,* which articulates with the quadrate, and the *dentary* which is encased in the horny lower jaw.

c. The *hyoid apparatus* consists of a *body* and two well developed *cornua.* The latter are derived from the third and fourth visceral arches. A more anterior pair of *hyoid cornua* is found in some turtles.

Cartilage and Membrane Bones. The skull of the turtle has both cartilage and membrane bones. The *cartilage bones* of the cranium are the occipitals, basisphenoid, and otics. All others are *membrane bones.* The upper jaw includes a single cartilage bone, the quadrate. In the lower jaw the articular is the only cartilage bone.

Drawing III. A ventral view of the skull. Label:

(1) basioccipital
(2) basisphenoid
(3) vomer
(4) prootic
(5) jugal
(6) squamosal
(7) quadrate
(8) pterygoid
(9) palatine
(10) quadratojugal
(11) jugal
(12) maxillary
(13) premaxillary

DRAWING IV. A lateral view of the skull. Label:

(1) squamosal
(2) quadrate
(3) tympanic fossa
(4) quadratojugal
(5) jugal
(6) maxillary
(7) premaxillary
(8) prefrontal
(9) frontal
(10) postfrontal
(11) parietal
(12) supraoccipital

DRAWING V. A lateral view of the lower jaw. Label articular and dentary bones.

APPENDICULAR SKELETON

The pectoral and pelvic girdles lie internal to the ribs. Note the three parts of the *pectoral girdle:* the dorsal *scapula,* the ventral *procoracoid* and *coracoid.* The coracoid is posterior. In turtles with a fixed plastron, ligaments attach the scapula and procoracoid to the shell, and movements of the girdle are limited to rotation about an axis passing through these points of attachment. The skeleton of the fore leg has a simple structure. Compare it with the skeleton of the human arm.

The *pelvic girdle* includes three bones on each side of the middle line: a dorsal *ilium,* which articulates with the two sacral vertebrae; and two ventral bones, the *ischium* and *pubis.* The pubis, which is anterior, bears a cartilaginous *prepubis* which will not be preserved in the dry skeleton. The skeleton of the hind leg should be compared with that of the leg of man.

DRAWING VI. The pectoral girdle and skeleton of the fore leg. Label the important parts.

DRAWING VII. The pelvic girdle and skeleton of the hind leg.

THE MUSCULAR SYSTEM

Obtain from the instructor a specimen for the study of the internal organs. On account of the presence of the shell, the muscular system is not well developed. The muscles of the girdles and the proximal muscles of the neck and tail arise within the shell, into which head, appendages and tail may be retracted.

With a small saw, cut through the lateral bridges which connect plastron and carapace. Then separate the soft tissues

from the inner surface of the plastron on one side. Note the attachment of the pectoral and pelvic muscles to the plastron, and the relation of the plastron to the procoracoid. Remove the plastron and observe the muscles of the girdles and the attachment of these muscles to the carapace. Compare the movability of the pectoral and pelvic girdles. The neck is retracted by a stout muscle which lies in the mesentery ventral to the dorsal vertebrae, from which the muscle arises. Note the position of the neck when it is fully retracted.

The Digestive System

After the removal of the plastron the internal organs are still covered by a layer of peritoneum. Observe the *heart,* which lies in the pericardial sack behind the pectoral girdle. In the peritoneum behind the heart are two *abdominal veins,* one on each side of the median line. They are connected posteriorly with the renal portal system, anteriorly with the veins of the liver. Cut through the peritoneum and follow the abdominal veins into the liver, then remove the peritoneum and expose the digestive organs. Identify the large two-lobed *liver,* the *gall bladder,* the *stomach* and the coiled *small intestine.* The *pancreas* lies in the gastro-hepatic ligament between the stomach and liver. Follow the small intestine backward and find the large intestine, or *colon,* the beginning of which is marked by a short *caecum.* A dorsal mesentery supports both small and large intestine. Locate the *urinary bladder,* then cut through the pelvis in the median ventral line and find the *cloaca,* into which the colon and bladder both open. The *anus,* or external opening of the cloaca, is on the ventral surface of the tail.

The mouth and pharynx will be described with the respiratory system.

Drawing VIII. The digestive organs.

The Circulatory System

Expose the heart by removing the pericardium, then compare the heart of the turtle with that of the frog. Observe the conspicuous arteries which arise from the ventricle, and the dark colored veins.

The Venous System. The venous system includes the *systemic* veins, *pulmonary veins,* the *hepatic portal system* and the *renal portal system.*

Two *pulmonary veins,* which accompany the bronchi from the lungs, may open into the auricle separately or through a short trunk formed by the union of the two veins. The *systemic veins* include right and left precavae, a post cava, and a left hepatic vein from the left lobe of the liver. Lift the ventricle and find the connection of these veins with the sinus venosus, then follow them peripherally and find their chief tributaries. Outside of the pericardium the *precava* is formed by the union of smaller veins, the most important of which are the *internal jugular vein* from the neck, and the *subclavian vein* which returns the blood from the fore leg. The *postcava* is formed between the kidneys by the confluence of the renal veins. From its origin the vein may be followed to the right lobe of the liver, through which it passes forward to reach the sinus venosus. The *hepatic portal vein* receives blood from the digestive tract and carries it to the liver, which the vein approaches by way of the hepato-duodenal ligament. The *renal portal vein* receives blood from the posterior part of the body and carries it to the kidneys. The two portal veins are connected by the two abdominal veins.

Drawing IX. The systemic veins. Label:

(1) precava
(2) internal jugular
(3) subclavian
(4) external jugular
(5) brachial
(6) postcava
(7) left hepatic vein

The Arterial System. Recall the plan of the circulation of the frog, especially the undivided ventricle and conus arteriosus and the two ventral aortae with their pulmonary and systemic branches. In the turtle the conus arteriosus is wanting and the pulmonary and systemic arteries arise separately from the ventricle. Two aortic arches are present, which are derived from the fourth pair of aortic arches of the embryo. An incomplete septum in the ventricle prevents to some extent the mixing of venous and arterial blood.

Observe the arterial trunks which arise from the ventricle of the turtle: a *pulmonary artery* and a *left aortic arch* from the

right side, a *right aortic arch* from the left side. The right aortic arch gives rise to an *innominate artery,* which divides at once into right and left *subclavian arteries* and right and left *carotids*. In the median line between these diverging arteries lies the *thyroid gland*. The branches of the subclavian artery run to the pectoral muscles and fore leg. The carotids supply the neck and head. Follow the left aortic arch and observe its branches to the stomach, intestine and pancreas. The two aortic arches unite dorsally to form the *dorsal aorta,* which gives off branches to the kidneys and reproductive organs, then divides into two *common iliac arteries* which supply the pelvic region and posterior legs.

Drawing X. The heart and larger arteries. Label:

(1) the auricles
(2) the ventricle
(3) pulmonary artery
(4) aortic arches
(5) innominate artery
(6) subclavian arteries
(7) carotid arteries
(8) dorsal aorta
(9) common iliac arteries

The Respiratory System

Because of the presence of a rigid shell the mechanism of pulmonary respiration is greatly modified in the turtle. When the animal is quiet, the force-pump mechanism is used, the air being forced into the lungs by elevation of the floor of the mouth, as in the frog. The active animal may employ a modified suction-pump mechanism, in which inspiration and expiration are effected by movements of the appendages and neck.

Obtain a living turtle and study the respiratory movements. If the head is retracted, place the animal in water deep enough to cover the shell. The head will then be extended to obtain air. Observe the oscillations of the floor of the mouth and pharynx. These movements probably supply oxygen to the mucous membrane of the internal cavity, but they are also used to force air into the lungs. Can you discover evidence of this? Pond turtles obtain a part of their oxygen by taking water into the mouth and pharynx. Look for movements of the lower jaw when the turtle is under water. Does water pass through the nasal cavity?

Remove the heart, liver, stomach and small intestine. The

lungs may now be seen through the layer of peritoneum which covers them. Find the bronchus which is connected with each lung and follow the two bronchi to the trachea. At the anterior end of the trachea is the larynx. Open the mouth widely, cutting the lower jaw on each side, if necessary. The internal cavity is a continuous space, which includes the mouth and pharynx. In the roof of this cavity are two pairs of openings: the *choanae* or internal nasal openings and the openings of the *Eustachian tubes* which lead to the middle ear. In the floor of the cavity is the *tongue,* which is supported by the hyoid apparatus. Behind the tongue is the *glottis,* the opening of the larynx. Inflate the lungs through the glottis. Examine the cartilages of the bronchi and trachea. The *larynx* is attached to the posterior horns of the hyoid apparatus. It is composed of a posterior ring of cartilage, called the *cricoid cartilage;* and a pair of *arytenoid cartilages* which guard the glottis. The cricoid cartilage is an enlarged ring of the trachea. The arytenoids are derivatives of one of the posterior visceral arches.

Drawing XI. The lungs, bronchi, trachea and larynx.

Drawing XII. The hyoid apparatus and larynx, dorsal view.

The Urogenital System

Remove the large intestine and study the urogenital system. The female organs consist of the *ovaries* and *oviducts.* The ovaries lie anterior to the cloaca, one on each side of the large intestine. They may contain eggs in various stages of development. The *oviducts* are convoluted tubes which open posteriorly into the cloaca. Remove the ovaries and find the *kidneys,* or *metanephroi,* which are attached to the dorsal wall of the body cavity at the anterior end of the cloaca. The straight *ureter* passes from the ventral surface of the kidney to the cloaca, through which the urine enters the bladder. Note the attachment of the bladder to the anterior end of the cloaca.

The male turtle has paired *testes* which are attached to the peritoneal covering of the kidneys, one on each side. From each testis arise several small tubules, the *vasa efferentia.* These unite to form the *vas deferens,* which opens into the

cloaca. The *epididymis* is a blackish body formed by the convoluted vasa efferentia and vas deferens. Open the cloaca by a longitudinal incision on one side and find the *penis,* which is attached to the ventral wall. The urinary organs of the male are similar to those of the female.

Thin walled sacks, one on each side of the cloaca in male and female turtles, are accessory respiratory organs which are used when the animals are in water. The sacks are filled with water through the anus.

DRAWING XIII. The male urogenital system.

DRAWING XIV. The female urogenital system.

THE NERVOUS SYSTEM

The Brain. Remove the dorsal bones of the skull and study the brain. Identify the parts of the brain and compare them with the corresponding parts in the frog. In the turtle the relatively large *cerebrum* meets the optic lobes and almost conceals the thalamencephalon. The *cerebellum* is a conspicuous lobe which overlaps the medulla. Note the *olfactory lobes* at the anterior end of the cerebrum, and the stalked *pineal body* which arises from the roof of the thalamencephalon. In all reptiles the cerebrum has a superficial layer of cells, the *cortex,* which contains the higher nervous centers. The cortex is highly developed in mammals.

The Cranial Nerves. Twelve *cranial nerves* are present in the turtle. Find their origin from the brain and trace them peripherally as far as possible.

1. The *olfactory* nerve connects the olfactory organ with the olfactory lobe of the cerebrum.
2. The two *optic* nerves cross below the thalamencephalon, from which point they run directly to the eyeballs.
3. The *oculomotor* nerve arises from the floor of the midbrain. It enters the orbit and supplies four muscles of the eyeball: the internal rectus, the superior rectus, the inferior rectus and the inferior oblique.
4. The *trochlear* nerve emerges from the roof of the midbrain anterior to the cerebellum. It supplies the superior oblique muscle.

5. The *trigeminus* nerve arises from the antero-lateral angle of the medulla. Two of its branches, the *ophthalmic* and the *maxillary,* enter the orbit, the former passing through the median part of the orbit to the nasal region; the latter, across the ventral part of the orbit to reach the upper jaw. The third, or mandibular branch of the trigeminus is a mixed nerve which supplies the lower jaw and the muscles which close the mouth.

6. The *abducens* nerve arises from the floor of the medulla. It supplies the external rectus muscle. Remove the right eyeball on one side after cutting the muscles close to their insertion, then identify the orbital nerves and trace them posteriorly to the brain.

7 and 8. The *facial and auditory* nerves arise together from the side of the medulla, behind the origin of the trigeminus. The auditory nerve runs directly to the internal ear; the facial nerve has a sensory *palatine* branch which runs to the roof of the mouth, and a *motor* branch which innervates the muscles which open the mouth.

9. The *glossopharyngeal* nerve arises from the medulla posterior to the origin of the preceding nerves. It supplies sensory fibers to the tongue and mixed branches to the wall of the pharynx.

10 and 11. The *vagus* and spinal *accessory* arise from the medulla together. The spinal accessory supplies certain muscles of the neck and shoulder. The vagus is a mixed nerve which innervates the larynx, pharynx, oesophagus, lungs, stomach and heart.

12. The *hypoglossal* nerve arises from the floor of the medulla. It is a motor nerve for the muscles of the tongue.

The Spinal Nerves and Sympathetic Nervous System. The spinal nerves include nine cervical, ten dorsal and two sacral nerves. Six or seven *dorsal nerves* can be easily seen after removal of the heart, digestive tract and lungs. Each nerve passes through a foramen in the middle of a vertebra, the first nerve emerging between the first and second ribs. The roots of the nerves unite outside of the spinal column and the ganglia of some of the dorsal roots are exposed. From the trunk of each nerve one or two branches run laterally across

the inner surface of the carapace. A third branch, the *visceral,* forms a connection with the sympathetic nervous system. Find the *brachial plexus,* a network of nerves formed by four or five posterior cervical nerves and the first dorsal nerve. The plexus supplies the muscles of the pectoral girdle and the fore limb. A *sacral plexus,* which innervates the posterior appendages, is formed by the eighth, ninth and tenth dorsal nerves and two sacral nerves.

The *sympathetic system* is represented in the dorsal region by two ganglionated cords, one on each side. The anterior part of each cord lies close to the spinal column; posteriorly it passes to the lateral surface of the great retractor muscle of the neck, where the ganglia may be seen. These ganglia are connected with the spinal ganglia by the visceral branches of the spinal nerves. From the dorsal region, the sympathetic cords pass forward to the neck and head, their cervical portions lying close to the two vagus nerves.

Drawing XV. The dorsal spinal nerves, the posterior cervical nerves, the brachial plexus and the dorsal part of the sympathetic nervous system. Show the parts observed.

The Sense Organs

The *ear* of the turtle is similar to that of the frog. Find the *tympanic membrane* and locate the point of attachment of the *columella.* The inner end of the columella is attached to the *stapes,* which is inserted in the *fenestra ovalis.* Cut around the margin of the tympanic membrane and examine the cavity of the middle ear, or *tympanum.* Find the opening of the *Eustachian tube.* Both tympanum and Eustachian tube arise from the first visceral cleft of the embryo. Do you understand the function of the columella and middle ear? The internal ear is similar to that of the dogfish and frog.

The eye. Find three eyelids, including a nictitating membrane. Remove the roof of the left orbit and study the contents of the cavity. Two glands lie between the eyeball and the wall of the orbit: an anterior *Harderian gland* and a posterior *lachrymal gland.* They lubricate the eyelids and the exposed parts of the eyeball. Remove the glands and find the four *recti muscles,* which arise from the posterior part of the

interorbital septum and are inserted on the eyeball. The *superior* and *inferior oblique muscles* lie in the anterior part of the orbit. Cut away the superior rectus muscle and find the *retractor muscle* of the eyeball. It arises from the interorbital septum and is inserted on the median part of the eyeball.

A large blood space, the *orbital sinus,* lies between the eyeball and the adjacent parts. Do you find blood in this part of the orbit? The sinus is drained by the internal jugular vein and may be flooded in the living turtle, by obstructing the vein in the posterior part of the head, where a special constrictor muscle surrounds the vein. The lizards have a similar mechanism which is used at the time of molting, when the skin in the region of the eye is stretched by flooding the orbital sinus. In a vigorous horned toad (Phrynosoma), or Florida chameleon (Anolis), the mechanism may usually be set in motion by applying a bit of court plaster to the eyelids behind the posterior angle of the eye.

Cut away the dorsal part of the eyeball and observe the cornea, sclera, choroid and retina; the internal and external chambers; the iris and pupil; the lens, which is supported by the ciliary processes of the choroid.

The nasal cavity. The external nares lie at the extreme anterior end of the head. The external opening leads into a narrow *vestibule* which is lined with stratified squamous epithelium. The vestibule opens into a wider chamber, the *true olfactory cavity,* which is lined with olfactory epithelium. A prominence, or *turbinal,* in the posterior part of this cavity greatly increases the area of the sensory epithelium.

Turtles smell both in air and water.

Phylum, CHORDATA
Subphylum, VERTEBRATA
Class, AVES
Order, CHARADRIFORMES
Columba domestica

The Domestic Pigeon

Birds resemble reptiles in many of their characteristics, especially in the structure of the skull, and in the excretory and

reproductive organs. A cloaca is present in both groups. Both produce large eggs, in which the young reach the adult stage before hatching. Birds are unlike reptiles because of their adaptations for flight, and because they are able to maintain a uniform high temperature.

If the laboratory is not provided with prepared skeletons, two specimens will be required for the study of the bird. A few skeletons should be available for reference during the study of the soft parts.

External Characteristics

Observe the various derivatives of the skin: *feathers, scales* on the feet, *claws* on the toes, *horny jaws*. Feathers are probably modified scales. The developing feather contains mesoderm and ectoderm, but the mesoderm withdraws as the feather matures. The scales and claws are similar to those of reptiles.

The body of the pigeon has four regions: head, neck, trunk and tail. Find the slit-like *external nares;* the *eyelids,* which include a nictitating membrane; the opening of the *external auditory meatus,* or external ear; the *anus,* or cloacal opening; the *oil gland,* which opens on the dorsal surface of the tail. Identify the parts of the wing: upper arm, fore arm, wrist and hand. The corresponding parts in the leg are the thigh, shank, ankle and foot.

Drawing I. A lateral view of the head. Label the parts described.

Three kinds of *feathers* may be recognized: contour feathers, down feathers and hair feathers. The *contour feathers* include ordinary covering feathers, or *coverts,* and large *quill feathers.* The quill feathers of the wings are called *remiges.* Those attached to the hand are *primaries;* those attached to the fore arm, *secondaries.* The quill feathers of the tail are called *rectrices.* Wing and tail coverts are ordinary contour feathers which cover the base of the quill feathers of the wings and tail, respectively. The *ala spuria* is a movable tuft of feathers at the lateral margin of the wing.

Study the parts of a contour feather: the transparent quill, or *calamus;* the expanded part, called the *vane;* the *shaft,* a

continuation of the calamus which forms the axis of the vane; two rows of *barbs* which arise from the shaft, one on each side; *barbules* which arise from the barbs in two rows, a distal row which bears *hooks*, and a proximal row which bears *flanges*. By the interlocking of hooks and flanges the parts of the feather are held together in a common plane. Use a microscope for the study of details.

Down feathers have no shaft. Hair feathers have a slender shaft with only a few small barbs. Find these under the contour feathers.

Drawing II. A dorsal view of the extended wing. Label the primaries, secondaries, outer wing coverts and ala spuria.

Drawing III. The structure of a contour feather.

The Air Sacs

The pigeon has a remarkable system of air sacs which arise from the bronchial tubes and extend in different directions from the lungs. They should be studied in a specimen which has been recently killed by means of chloroform or ether.

Carefully cut through the skin in the midventral line from the anterior end of the breast to the anus. Remove the skin from the entire trunk region and from the neck, but not from the head. Do not injure the crop, which lies under the skin, ventral to the base of the neck. Does the crop contain food? Identify the *trachea*, then open the mouth widely and find the respiratory aperture, the *glottis*, which lies behind the tongue. Insert a small tube in the glottis and inflate the lungs and air sacs. Observe that the entire trunk is inflated. To prevent the escape of air the trachea may be tied. Some of the air sacs may now be visible in the region of the crop. If they are not found, separate the dorsal and lateral margins of the crop from the adjacent parts. Two small *cervical air sacs* lie at the base of the neck above the trachea. A single *interclavicular sac* lies ventral to the cervical sacs and lateral from the trachea and oesophagus.

Open the abdominal cavity by removing the ventral portion of the body wall between the sternum and the anus. The paired *abdominal air sacs* lie dorsal and lateral to the intestine.

When inflated they may reach the posterior end of the abdominal cavity. Anterior to these are the *posterior* and *anterior thoracic air sacs,* which lie between the alimentary tract and the lungs. The lateral parts of these sacs are attached to the inner surface of the ribs and may be seen by pushing the viscera away from the body wall. All air sacs have branches which pass between organs or penetrate bones. The entire respiratory system may be inflated through the broken humerus.

The air sacs probably carry oxygen directly to the tissues; they also increase the efficiency of the lungs, because they receive the residual air from the lungs during inspiration and thus make it possible for fresh air to enter the lungs.

The Muscular System

Since the vertebrae of the trunk are practically immovable, the muscles of the dorsal trunk region are not well developed. The most conspicuous muscles of the body are those which move the appendages: the muscles of the breast, wings and legs. Only the pectoral muscles will be studied.

The Pectoral Muscles. The chief muscles in this group are the pectoralis major which depresses the wing, and the pectoralis minor which elevates it. The *pectoralis major* forms the greater part of the muscle mass on each side of the sternum. Its fibers arise from the body and keel of the sternum and from the clavicle (wishbone). The muscle is inserted by a strong tendon on the proximal portion (lesser trochanter) of the humerus. Sever the attachment of the pectoralis major to the keel of the sternum and to the clavicle, and push the muscle laterally. The tendon can be seen on the inner surface of the muscle and should be followed to its insertion. The *pectoralis minor* may now be found in the angle between the body and keel of the sternum. Its fibers arise from the sternum and from the coracoid. From its anterior end a tendon passes through a foramen formed by the clavicle, scapula and coracoid, the *foramen triosseum,* and is inserted on the dorsal surface of the humerus. Open the foramen by separating the clavicle and coracoid anterior to the shoulder joint and follow

the tendon to its insertion. Demonstrate the function of these two muscles. Anterior to the body of the pectoralis minor lies the small *axillary air sac,* a branch of the interclavicular sac. The axillary sac opens into the humerus through an opening, the *pneumatic foramen,* which lies in the pneumatic fossa, near the proximal end of the bone.

The Digestive System

Open the mouth widely, cutting the posterior ends of the lower jaw, if necessary. Examine the internal cavity, which includes both mouth and pharynx. In the floor of the mouth region is the *tongue;* in the roof are two palatal folds which almost cover the slit-like *internal nares.* In the floor of the pharynx is the *glottis,* which lies behind the tongue. In the roof, behind the palatal folds, is the single opening of the two Eustachian tubes. In the posterior part of the pharynx, two additional pairs of folds may be seen, one posterior to the glottis, the other posterior to the Eustachian opening.

Drawing IV. a. The roof of the mouth and pharynx. b. The floor of the mouth and pharynx.

Remove the pectoral muscles, then cut through the ribs and shoulder girdle on each side of the sternum. Lift one side of sternum, and find the *ventral mesentery* which passes from the sternum to the internal organs; also the small *sternotracheal muscles,* which arise from the anterior end of the sternum and are inserted on the trachea anterior to the syrinx. Remove the sternum. Observe the location of the heart, then continue the study of the digestive organs.

The *crop* is an enlarged portion of the oesophagus and is used for the storage and softening of the food. It also furnishes a secretion, called *pigeon's milk,* which is fed to the young. From the crop, the oesophagus continues posteriorly to the *glandular stomach,* which lies dorsal to the liver. Posterior to the glandular stomach is the large muscular *gizzard.* The *small intestine,* which follows the gizzard, is a long, convoluted tube. The *large intestine,* which is relatively short, bears two small *caeca* at its anterior end; posteriorly it opens into the short, wide *cloaca.* The *pancreas* lies between the two arms of

the duodenum, which forms a loup behind the gizzard. The two-lobed *liver* has two bile ducts which open separately. Follow them through the hepato-duodenal ligament, a small messentery which extends from the liver to the duodenun. Observe the dorsal *mesentery* which supports both small and large intestine. The cloaca will be studied in connection with the urogenital system.

Drawing V. The liver, gizzard, small and large intestine, caeca and the cloaca.

The Circulatory System

Remove the pericardium and expose the heart. Identify auricular and ventricular portions. The latter is completely divided in birds. A sinus venosus is wanting.

The Arteries. Two arterial trunks arise from the heart: the aorta and the pulmonary artery. The *aorta,* which represents the right fourth aortic arch of the embryo, gives rise to two *innominate arteries,* then bends dorsally to form the dorsal aorta. Each innominate artery divides into a small *carotid artery* which runs to the neck and head, and a larger *subclavian* artery which supplies the pectoral muscles and wing. The *pulmonary artery* divides near the heart into two branches, one for each lung.

The dorsal aorta. Trace the dorsal aorta from the region of the heart and find the following branches: the *coeliac artery,* whose branches run to the stomach, liver and pancreas; the *anterior mesenteric* artery which supplies the small intestine; the *posterior mesenteric* artery which carries blood to the large intestine. Paired branches of the dorsal aorta include renal arteries, and two large sciatic arteries which enter the legs.

The Veins. Two precavae and a postcava open into the right auricle, the pulmonary vein into the left auricle. The *right precava* is a short vein which is formed by the union of three tributaries: the *jugular,* which returns blood from the neck and head; the *subclavian,* which collects blood from the arm; the *pectoral,* which drains the pectoral muscle. Three tributaries, corresponding to those of the right precava, form the *left precava,* which runs across the dorsal surface of the

heart to reach the right auricle. The *postcava* is formed near the anterior end of the kidneys by the union of two *iliac veins*, which receive blood both from the kidneys and from the legs. On its way to the heart the postcava passes through the right lobe of the liver. The *hepatic portal vein*, which runs to the liver through the hepato-duodenal ligament, has three tributaries: a gastro-duodenal vein which receives blood from the duodenum, gizzard and a part of the small intestine; an anterior mesenteric vein, which brings blood from the greater part of the small intestine; the posterior mesenteric vein, which collects blood from the large intestine.

DRAWING VI. The heart and systemic veins. Label the right auricle, right and left precavae, jugular vein, subclavian vein, pectoral vein, postcava, iliac veins.

DRAWING VII. The heart and arteries. Label the right and left ventricles, right and left innominate arteries, carotid artery, subclavian artery, dorsal aorta, coeliac artery, anterior mesenteric artery, posterior mesenteric artery, sciatic arteries, the pulmonary artery.

The Heart. Remove the heart and study its internal structure under water. Cut away the apex of the ventricles and compare the thickness of the wall of the right and left sides. Cut through the wall of the heart on each side from the auricle to the ventricle and study the valves. The *auriculo-ventricular valves* guard the openings between auricles and ventricles. The right valve consists of a single muscular flap, which extends into the ventricle from the margin of the auriculo-ventricular opening. The left auriculo-ventricular valve has two flaps of connective tissue which are held in place by strong cords, *chordae tendineae*, attached to the wall of the ventricle. The *semilunar valves* lie at the openings of the ventricles into the aorta and pulmonary artery. Cut open the arteries and find three pocket-shaped valves at the posterior end of each one. Do you understand the operation of the valves of the heart?

Compare the circulatory system of the bird with that of the turtle.

DRAWING VIII. The interior of the heart, left side. Show the auriculo-ventricular valve and the chordae tendineae.

DRAWING IX. The semilunar valves at the posterior end of the aorta.

The Respiratory System

Remove the crop, stomach, liver and small intestine and expose the lungs, which lie dorsal to the thoracic air sacs. The respiratory system includes the larynx, trachea, two bronchi, the lungs and the air sacs. Air enters the system through the nasal cavity, mouth and pharynx. The glottis opens into the larynx.

The *larynx,* which lies between the long posterior horns of the hyoid apparatus, consists of the following cartilages: the paired *arytenoid* cartilages which guard the glottis; the U-shaped cricoid cartilage which lies posterior to the arytenoids, with its two arms directed dorsally; a short bar of cartilage, the *procricoid,* whose anterior end lies between the two arytenoids, its posterior end between the arms of the cricoid cartilage. The arytenoids are derivatives of the visceral skeleton; the cricoid and procricoid are modified rings of the trachea. In birds the larynx is not used as a vocal organ. Posterior to the larynx is the trachea, which forks at the posterior end to form the two bronchi, one for each lung.

The *lungs* lie between the thoracic air sacs and the roof of the thorax. They are spongy organs of relatively small size, and capable of little distension. After entering the lung the *bronchus* gives rise to *secondary bronchi,* some of which divide to form the substance of the lung, while others pass undivided to the surface of the lung, where they open into the *air sacs.* At the posterior end of the lung are two openings, one of which leads to the abdominal air sac, the other to the posterior thoracic sac. Secondary bronchi of the anterior part of the lung open into the cervical, anterior thoracic and interclavicular air sacs.

The *syrinx,* or vocal organ of the pigeon, is formed by the posterior end of the trachea and the adjacent parts of the two bronchi. Observe the external form of the syrinx, then remove the lateral wall of both tracheal and bronchial portions on one side and find the *semilunar membrane,* a vertical fold which extends into the trachea from the partition between the two bronchi. Sound waves are produced by the vibration of the semilunar membrane. Two paired muscles are supposed to

change the character of the sounds: the *bronchotracheal muscles,* which are attached to the trachea, one on each side, anterior to the syrinx; the *sternotracheal muscles,* which arise from the anterior end of the sternum and are inserted on the ventral surface of the trachea.

DRAWING X. A ventral view of the entire respiratory system: larynx, trachea, syrinx, sternotracheal muscles, bronchotracheal muscles, bronchi, lungs, openings of the air sacs, if they can be seen.

DRAWING XI. The interior of the syrinx, viewed from one side.

THE UROGENITAL SYSTEM

The Male. The kidneys, or *metanephroi,* are three-lobed organs, which are closely applied to the inner surface of the pelvis. From each kidney a straight ureter passes to the cloaca. The *testes* are two oval bodies which are attached to the ventral surface of the kidneys. From each testis a coiled *vas deferens* passes to the cloaca. In the pigeon the vas deferens serves only as a sperm duct.

The Female. Only the left ovary and oviduct are normally developed. The *ovary* may usually be recognized by the eggs which it contains. The *oviduct* is a wide convoluted tube with a conspicuous fringed *ostium.* During its passage through the oviduct the egg is covered with albumen, shell membranes and the shell. A rudimentary right oviduct may be found attached to the right side of the cloaca. The excretory organs of the female are like those of the male.

The cloaca. Cut through the wall of the cloaca in the mid-ventral line and examine the interior. The anterior end is divided by a horizontal partition into two parts, a dorsal one which receives the openings of the urogenital ducts, and a ventral one which is connected with the large intestine. The dorsal chamber is larger in the female than in the male. In young pigeons the dorsal wall of the cloaca bears a small pouch, the bursa of Fabricius, whose function is unknown. It usually disappears in the adult bird.

DRAWING XII. The urogenital system of the male.

DRAWING XIII. The urogenital system of the female.

The Nervous System

Carefully remove the roof of the cranium and expose the brain. Observe the relatively large size of the *brain* as a whole, and the peculiar form and relation of its parts. The cerebrum and cerebellum meet above the midbrain and the optic lobes are forced into a lateral position. The large size of the cerebrum is due, not to an increase in the cortex, but to the enlargement of an internal center, the *corpus striatum,* which seems to be used in flying. Cut away a part of the roof of the cerebrum on one side and note the large corpus striatum, which almost fills the ventricle. The large optic lobes correspond to the large size of the eyes and to the general importance of vision in the bird. The olfactory lobes are small. The pineal body may be seen in the angle between the posterior ends of the cerebral hemispheres.

Drawing XIV. A dorsal view of the brain.

The eye. Remove the roof of the right orbit and examine the contents of the cavity. Push the eyeball laterally and find the *optic nerve.* The muscles which move the eyeball are similar to those of the lower vertebrates. Four *recti* and two *oblique muscles* are present. Two small muscles which move the nictitating membrane are attached to the median surface of the eyeball: the *quadratus* which lies above the optic nerve, and the *pyramidalis* which lies below it. Two glands furnish secretion for the eyelids and the exposed surface of the eyeball; the *Harderian* gland which lies anterior to the eyeball, and a small *lachrymal gland* which lies postero-ventral from the eyeball.

Cut away the dorsal part of the *eyeball* and observe the following: the layers of the eyeball, sclera, choroid and retina; the iris and pupil; the external and internal chambers; the lens, which is supported by the ciliary processes of the choroid; the pecten, a fan-shaped body which is attached to the point of entrance of the optic nerve. The function of the pecten is unknown. Find a ring of bony plates which lie in the sclera behind the cornea. The muscles of the iris and the muscles of accommodation are striated in birds. This makes possible rapid changes which are important in flight.

Drawing XV. The structure of the eyeball.

The *ear* of the pigeon is composed of three parts: external, middle and internal. The external ear is a short tube called the *external auditory meatus,* which is closed internally by the tympanic membrane. The middle ear, or tympanum, is similar to that of the turtle and frog. The sound-transmitting apparatus of the middle ear is a slender rod composed of *columella* and *stapes,* the former attached to the tympanic membrane, the latter to the *fenestra ovalis.* Expose the tympanic membrane by cutting away the ventral margin of the auditory meatus. The point of attachment of the columella is indicated by a slight elevation. Cut around the dorsal margin of the tympanic membrane and observe the attachment of the stapes to the median wall of the tympanic cavity. The opening of the Eustachian tube lies in the antero-ventral part of the cavity. Pass a small probe into the tube. The right and left Eustachian tubes have a common opening into the pharynx. External ear, middle ear and Eustachian tube are all derived from the first visceral cleft of the embryo. The parts of the internal ear are similar to those of lower vertebrates, excepting the *lagena,* which is much elongated. The sense of hearing is well developed in birds.

The olfactory organ. With scissors cut away the lateral wall of the nasal cavity posterior to the external naris. Three prominences, called *conchae* or *turbinals,* project into the cavity from the median wall. Only the posterior concha is concerned in smell; the others regulate the temperature and moisture of incoming air.

Drawing XVI. The nasal cavity and conchae.

The Skeleton

It is desirable that mounted skeletons should be available, but entire skeletons or parts, held together by the natural ligaments, should also be prepared by the student.

Study the skeleton as a whole. Many bones are fused together, especially in the appendages, spinal column and skull. The skeleton of the trunk forms an almost rigid support for the

appendages. The bones of the wings and legs and their girdles are strong, because each one must bear the entire weight of the body. Many bones contain air cavities.

The spinal column. Identify the following groups of vertebrae: (1) Fourteen *cervical vertebrae.* The two anterior vertebrae are the atlas and axis. They articulate by a pivot joint; the posterior vertebrae by saddle-shaped joints. Observe carefully the nature of these articulations. The two posterior vertebrae bear short ribs which do not reach the sternum. The last cervical vertebra is fused with the first dorsal. (2) Five *thoracic vertebrae.* All of these bear ribs, which articulate with the sternum. Three anterior vertebrae are fused together, the fourth is free, and the fifth is fused with the sacrum. (3) Fourteen or fifteen *sacral vertebrae.* They are fused together to form a compound sacrum, or synsacrum, which includes, in addition to the true sacral vertebrae, the last dorsal, the lumbar, and five caudal vertebrae. (4) Nine to eleven *caudal vertebrae.* These include four or five separate vertebrae and five or six fused vertebrae, the latter forming the *pygostyle.* How may this fusion of caudal vertebrae be explained? Compare the tail of the pigeon with that of *Archaeopteryx,* as described in Hegner.

The ribs. Each rib articulates with the spinal column by *two heads,* between which is the vertebrarterial canal, for the *vertebra artery.* Each thoracic rib consists of two parts, a *dorsal part* articulating with the vertebra, and a *ventral part* which articulates with the sternum. These articulations provide for movement of the ribs during respiration. Note the overlapping *uncinate processes* by means of which the dorsal parts of adjacent ribs are connected.

The *sternum* is the largest bone in the skeleton. It has two chief parts, the *body* and the projecting *keel,* the latter being a special development for the attachment of the muscles of flight. Compare the sternum of the pigeon with that of the domestic chicken; with that of the ostrich.

THE SKULL

Many of the bones are fused together in the adult pigeon. Locate the external nares, the orbits, the auditory fossae and

the foramen magnum. The floor of the skull is incomplete except in the region of the cranium, and the visceral portion is relatively distinct.

The Cranium. The foramen magnum is surrounded by the fused occipitals, the basioccipital bearing a *condyle* which articulates with the atlas. The *otic* bones are fused with adjoining parts. In the roof of the cranium, *parietals, frontals* and *nasals* form a continuous shield. In the large orbit, the central area is occupied by the bony *interorbital septum,* formed by the fusion of smaller bones. Above the septum lies the *frontal;* posterior to it, the *alisphenoid;* anterior to it, the *lachrymal,* or prefrontal, a small bone which may be lost during the preparation of the skeleton. In the floor of the cranium anterior to the basioccipital is the *parasphenoid,* whose posterior portion underlies both cranium and otic capsules, while its slender anterior process is fused with the ventral margin of the interorbital septum. The posterior part of the parasphenoid covers a smaller basisphenoid, the two bones being fused together in the adult bird.

The Visceral Skeleton. To this group belong the bones of the jaws, the hyoid apparatus, the bones of the middle ear and the cartilages of the larynx. The parts of the larynx have been described in connection with the respiratory apparatus; the ear bones, in connection with the ear.

a. The *upper jaw.* The anterior bones of the upper jaw are the two *premaxillae* which are fused together to form the upper part of the beak. In the living bird they are encased in the horny upper jaw. Examine the floor of the mouth. Behind the premaxilla, on each side, are two bony arches which articulate posteriorly with the *quadrate,* a triradiate bone which lies anterior to the tympanic fossa. The *lateral arch* is composed of an anterior *maxilla,* a middle *jugal* and a posterior *quadratojugal,* all of which may be fused together so that their boundaries can not be seen. The quadratojugal articulates with the quadrate, which is movable. The median arch is composed of two bones: a slender *palatine* which meets the palatine portion of the premaxilla, and a stouter *pterygoid* whose posterior half bends laterally to articulate with the quadrate. In the cranial

wall above and behind the tympanic fossa is a fixed bone, the *squamosal,* with which the quadrate articulates above the fossa.

Observe that both median and lateral arches are connected posteriorly with the movable quadrate, anteriorly with the premaxilla, which is also somewhat movable. This arrangement makes it possible to elevate the premaxilla when the mouth is opened, thus increasing the distance between the jaws. In some birds, such as the parrots, these movements are well developed.

b. The *lower jaw.* The most conspicuous bones of the lower jaw are the *articular* and *dentary.* The dentary is enclosed in the horny lower jaw; the articular forms a movable joint with the quadrate.

c. The *hyoid apparatus* consists of a *body* which has three segments, and two pairs of *cornua,* the posterior pair being much elongated. The anterior segment of the body is embedded in the tongue, whose posterior angles contain the short anterior cornua.

DRAWING XVII. A lateral view of the skull.

DRAWING XVIII. A ventral view of the skull.

THE APPENDICULAR SKELETON

a. The strong *pectoral girdle* is composed of three bones: a short stout *coracoid,* which is attached to the anterior end of the sternum; the *scapula,* which lies external to the ribs; the *clavicle,* which unites with its fellow to form the *furcula,* or wishbone. These three bones meet at the shoulder and form a strong support for the wing. A shallow cavity, glenoid fossa, which receives the head of the humerus, is formed by the coracoid and scapula.

DRAWING XIX. A lateral view of the thoracic vertebrae, ribs, pectoral girdle and sternum. Label all parts described.

b. The *wing* contains the usual bones in the region above the carpus. The distal part of the wing skeleton is modified both by the loss of bones and by fusion of those that remain. Only two free carpal bones are present; the others are fused with the metacarpus to form the *carpo-metacarpus,* which in-

cludes two elongated bones. From these arise *three digits,* which probably correspond to the second, third and fourth fingers of man. The first and most *anterior digit* is a short conical bone which articulates with the proximal part of the larger carpo-metacarpal bone. It supports the small movable ala spuria, or "bastard wing." The long *middle digit* is composed of two phalanges, the first of which articulates with the distal end of the carpo-metacarpus. The *fourth digit* has a single phalanx which lies behind the basal part of the third digit.

Drawing XX. A lateral view of the wing skeleton. Label all parts.

c. The *pelvic girdle* is composed of three fused bones: a large anterior ilium, a posterior *ischium,* and a slender postero-lateral *pubis*. The ilium and ischium are fused with the sacrum. The ischia and pubes of opposite sides do not unite ventrally in the pigeon. The acetabulum, a cup-shaped socket, which receives the head of the femur, lies at the junction of the three pelvic bones.

Drawing XXI. A dorsal view of the pelvic girdle, sacrum and tail.

d. *The skeleton of the leg.* Locate the knee and ankle. Do you find separate ankle bones. Above the knee is the short stout femur; below is the long tibio-tarsus, or drum stick which is formed by the fusion of the tibia with three upper metatarsal bones. Attached to the upper portion of the tibia is the rudimentary fibula. Below the ankle lies a single bone, the tarso-metatarsus, which is formed by the fusion of the distal tarsal bones with three metatarsals. At the lower end of the bone the metatarsals become separate, each division forming a knob for the articulation of one of the toes. The short first metatarsal is movable and its toe can be opposed to the others when the bird is at rest. Observe that the bird walks on its toes. The elevated metatarsus adds greatly to the length of the leg.

Drawing XXII. Lateral view of the skeleton of the leg. Label all parts described.

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